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THE HISTORY OF THE  
CITY OF BOSTON  
FROM 1630 TO 1880

BY  
JOHN H. COOPER

VOLUME I  
1630-1700

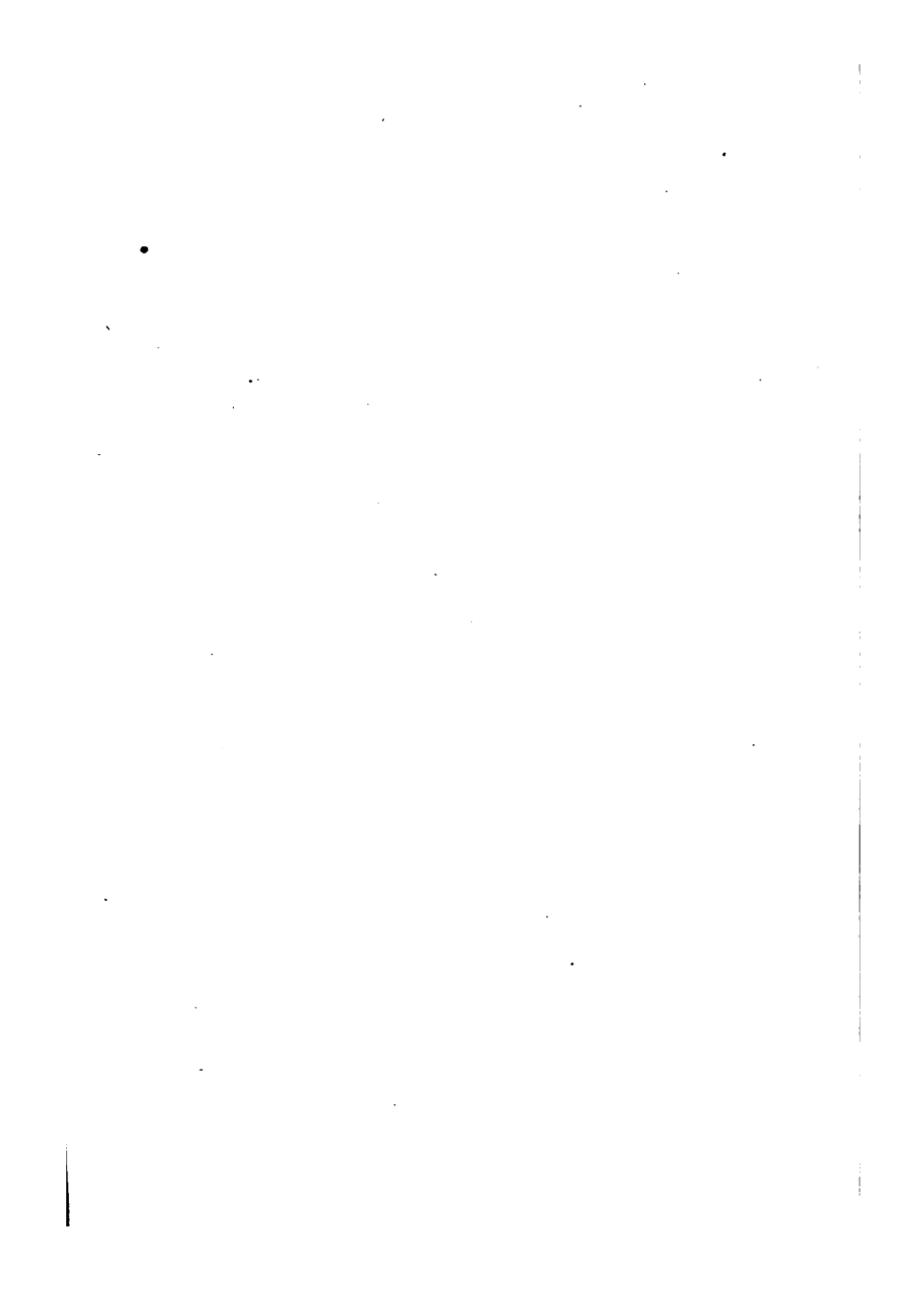
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**MODERN**  
**ELEMENTARY CHEMISTRY**



CATECHISM  
OF  
MODERN ELEMENTARY CHEMISTRY

OR  
SOLUTIONS OF THE QUESTIONS SET AT THE  
LONDON UNIVERSITY MATRICULATION EXAMINATIONS 1844-82

BY  
E. W. V. VOLCKXSOM, F.C.S.  
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*'Rien ne se perd, rien ne se crée dans la nature'—Lavoisier*

LONDON  
KEGAN PAUL, TRENCH, & CO., 1 PATERNOSTER SQUARE  
1882

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## PREFACE.

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It is confidently hoped that this little Manual will not be without interest to those persons who have never had the opportunity of attending a course of Chemistry, and who at the same time are desirous of making themselves acquainted with the principles and facts of a science to which reference is being continually made in the literature of the day and in ordinary conversation.

But its value for candidates at Matriculation of the London University cannot be overrated, as it contains the answers to all the questions which have been set at that examination for about forty years. These questions have been arranged in the order of matter; several have been subdivided, and about two dozen have been supplied which were never asked, but still fall within the matter of the syllabus. These last are marked with an asterisk. To each question has been appended the date of the examination in which it was set. These dates will thus show how frequently any question has been repeated, and will therefore indicate

to students and teachers the points upon which special stress should be laid.

In conclusion, the author begs to acknowledge his indebtedness to the excellent text-books of Roscoe, Miller, Wilson, Barff, Swartz, Würtz, and others, which have been freely referred to.

DOWNSIDE COLLEGE, BATH:

*June 1882.*

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SHOWING FROM A FEW EXAMPLES THE KIND OF NOMENCLATURE  
USED THROUGHOUT THIS MANUAL.

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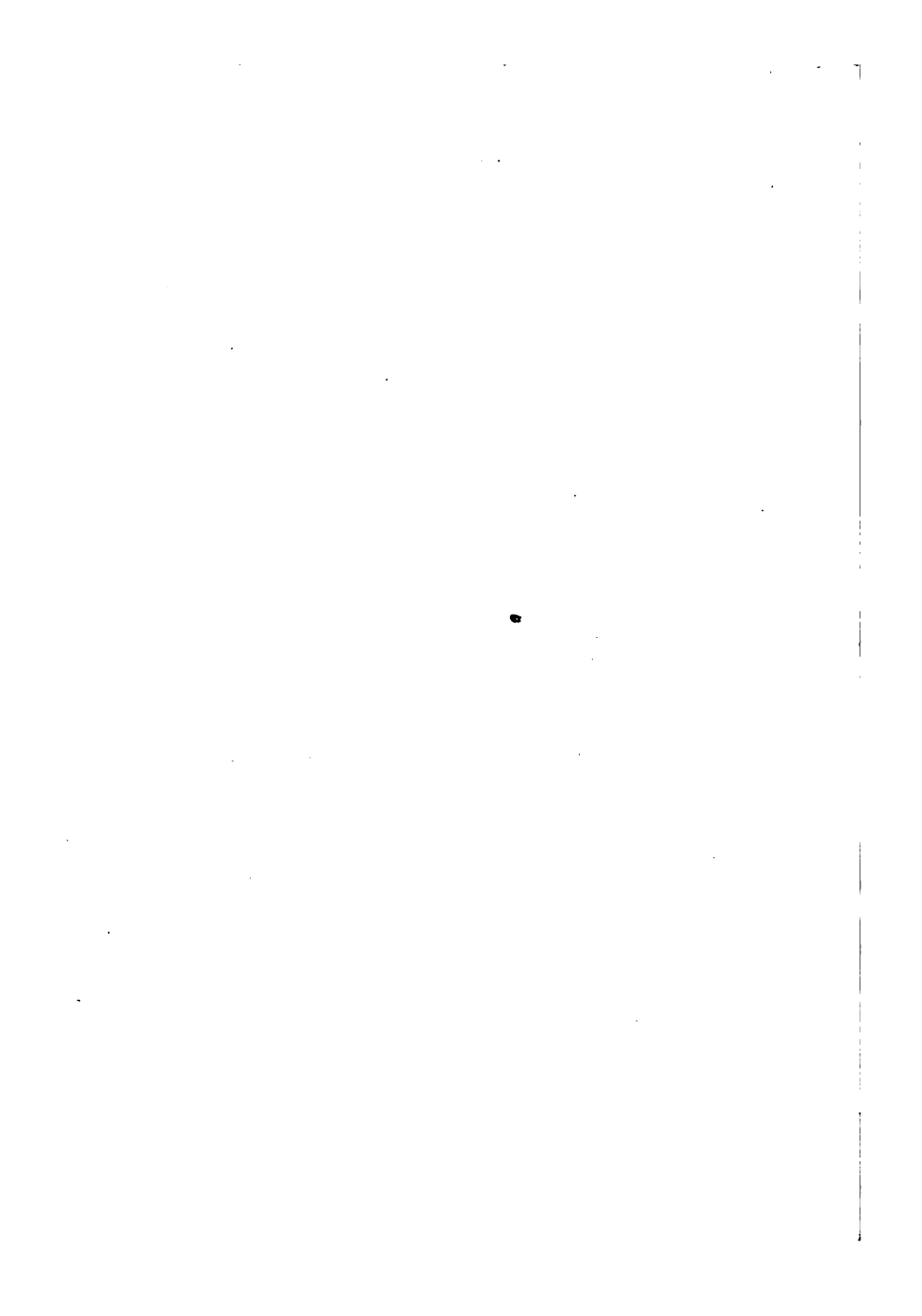
<b>Hydric sulphate</b> ( $\text{H}_2\text{SO}_4$ ),	instead of sulphuric acid—hydrogen sulphate—sulphate of hydrogen—oil of vitriol.
<b>Hydric sulphide</b> ( $\text{H}_2\text{S}$ ),	instead of sulphuretted hydrogen—sulphide of hydrogen—sulphydric acid.
<b>Hydric chloride</b> ( $\text{HCl}$ ),	instead of hydrochloric acid—chlorhydric acid—muriatic acid—spirits of salts.
<b>Calcic oxide</b> ( $\text{CaO}$ ),	instead of oxide of calcium—calcium oxide—caustic lime—lime.
<b>Carbonic dioxide</b> ( $\text{CO}_2$ ),	instead of carbonic acid—carbonic anhydride—choke damp.
<b>Sulphurous dioxide</b> ( $\text{SO}_2$ ),	instead of sulphurous acid—sulphurous anhydride—monothionic sulphurous acid.
<b>Sulphuric trioxide</b> ( $\text{SO}_3$ ),	instead of sulphuric acid—sulphuric anhydride—anhydrous sulphuric acid—monothionic sulphuric acid.
<b>Nitric trioxide</b> ( $\text{N}_2\text{O}_4$ ),	instead of nitric peroxide—hyponitric acid—nitrogen peroxide.
<b>Phosphoric pentoxide</b> ( $\text{P}_2\text{O}_5$ ),	instead of phosphoric acid—phosphoric anhydride—anhydrous phosphoric acid.
<b>Potassic chlorate</b> ( $\text{KClO}_3$ ),	instead of potassium chlorate—chlorate of potassium—chlorate of potash.

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# PRELIMINARY NOTIONS.

ELEMENTS, CHEMICAL COMBINATIONS, LAWS OF  
COMBINATION.

ACIDS, BASES, AND SALTS. SYMBOLS AND  
NOMENCLATURE.



## PRELIMINARY NOTIONS.

**1.\*** What is the object of the science of Chemistry?

Chemistry has for its object the investigation of the *composition* of different kinds of matter, and the *changes* in the composition which result from the action of one kind of matter upon another of the same kind, or of external forces upon matter.

**2.\*** In what does Chemistry differ from the science of Natural Philosophy?

It differs in this, that Natural Philosophy investigates the *properties* of all bodies, and the *changes* these bodies undergo, except changes of composition.

**3.\*** By what processes does Chemistry attain its object?

By the processes of analysis and synthesis.

**4.\*** In what does the process of analysis consist?

It consists in **resolving** compound bodies into more simple bodies.

\* The numbers to which asterisks are attached indicate questions not yet asked in the London University papers, but inserted here in order to supply a somewhat complete chemical course.

**5.\*** In what does the process of **synthesis** consist?

It consists in **building up** a compound body from more simple bodies.

**6.\*** By what name are those bodies called that have hitherto resisted **analysis** or **decomposition** into more simple bodies?

They are called **elements**. The number of clearly defined elements is about **sixty-five**.

**7.** Why do you call oxygen, hydrogen, and carbon chemical elements? *June 1871.*

Because these bodies have not been decomposed hitherto into two or more other bodies.

**8.** Explain why oxygen, hydrogen, nitrogen, and carbon are considered to be *elements*. Describe one experiment by which you could prove that diamond and graphite consist of the same element. *Jan. 1867.*

These bodies are considered to be *elements*, because, in the present state of science, they cannot be decomposed into two or more substances.

Diamond and graphite consist exclusively of the element carbon, because, if each substance be completely burned in oxygen, the result is the same, namely, the production of carbonic dioxide, as may be proved by passing the gas into lime-water, when a white precipitate is produced in each case.

**9.** Why are oxygen and mercury considered to be chemical elements? *June 1879.*

Because they are not known to contain any other elements but oxygen and mercury respectively, or because the actual state of science has not enabled any one to decompose them into two or more elements.

**10.** What are the principal distinctions between metallic and non-metallic elements? *July 1844.*

The elements have been divided for convenience into two classes—namely, the metallic and the non-metallic elements. This division is not rigorous, for the two classes run into each other. The principal distinctions may be thus noted: the **non-metallic elements** are electro-negative, have no metallic lustre, have a low specific gravity, and are bad conductors of heat and electricity; the **metallic elements** are electro-positive, have metallic lustre and a high specific gravity, and are good conductors of heat and electricity.

**11.** Define the expressions **chemical affinity** and **cohesion**. *July 1857.*

**Chemical affinity** is the force which causes different kinds of matter to combine—that is to say, to form compounds differing in their properties from the original substances. The act of union is called **chemical combination**, and the body resulting from this union is called a **chemical compound**. This force acts between atoms, or the smallest conceivable particles. **Cohesion** is the force which causes the various parts of the same body to adhere together, so as to resist separation. This force acts between larger masses of matter than *atoms*.

**12.\*** What is a **mixture**?

A **mixture** is the mechanical union of two or more bodies in no one definite proportion, each body, moreover, being present with its own composition and properties, without having undergone any change.

**13.** Two powders are given you: one is a me-

chanical mixture, the other a chemical combination, of sulphur and iron. In what respects would the powders differ, and by what chemical reactions could you distinguish the one from the other? *Jan. 1876.*

A given powder is composed of 32 gr. of sulphur and 50 gr. of iron. How would you ascertain whether the powder is a mechanical mixture or a chemical combination of the two elements? *June 1878.*

The two powders would differ in their physical appearance. The mechanical mixture would be easily pulverised, and would be of a greyish appearance. The chemical combination would be hard, and of a blackish colour.

To ascertain which is the mixture and which the combination, I should first reduce both to powder, and hold a magnet near each. In one the free iron would at once be attracted by the magnet, whereas the combined iron in the other could not be attracted.

Also, I should pour on the two powders some diluted hydric chloride. In the case of the mixture, hydrogen would be generated, whilst in that of the chemical combination hydric sulphide would be given off.

Again, the powders may be stirred up in water. After a part has been allowed to settle, the liquid should be poured off and allowed to settle again. In the mixture the first sediment is chiefly iron, the second sulphur; in the compound there is no difference in the nature of the sediment.

Carbonic disulphide dissolves sulphur from the mixture, but not from the compound.

Under the microscope, particles of iron and sulphur are distinguished in the mixture, but not in the compound.

14. A gas is found by analysis to consist of equal volumes of chlorine and hydrogen. Describe fully how you find by experiment whether the gas is a mechanical mixture or a chemical combination of the two elements. *Jan. 1875.*

I would find it out by the following experiments:—

(1) If the gas fumes when exposed to the air, the two elements are chemically combined.

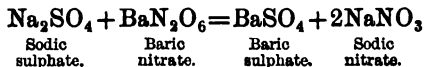
(2) If a greenness is still discernible, then the gases are not combined.

(3) If a light be applied to the jar containing the gases, or the jar be exposed to the direct rays of the sun, and an explosion ensues, then the two gases were present merely as a mixture.

(4) If, when a rod dipped in ammonia is applied to the opening of the jar, white fumes begin to form, the two gases are in chemical combination.

15. Explain what is meant by a double decomposition, taking the decompositions which occur on mixing solutions of sulphate of soda and nitrate of baryta, or any other instance, in illustration. *July 1846.*

By double decomposition is meant the fact that both bodies decompose, the acid of the one combining with the base of the other. Thus, for instance, mix a solution of sodic sulphate with baric nitrate. A white precipitate of *baric sulphate* is formed, which in a short time settles at the bottom of the vessel, the sodic nitrate remaining dissolved.



16.\* Explain in a few words in what the atomic theory consists.

It consists in the *conjecture* that all bodies are composed of a finite but very great number of invisible and indivisible particles (*atoms*); that, for each kind of element, these particles are identical in shape, size, and weight, but differ in different kinds of bodies. The actual shape, size, and weight of one of these particles are unknown, but the relative weight of the particles of different bodies is known, and this constitutes the *relative weight* or *atomic weight* of the bodies. This theory was devised and framed by Dalton, in order to explain the laws of chemical combination.

**17.\* Define an atom and a molecule.**

An **atom** is the smallest quantity of an element capable of existing in combination.

A **molecule** is the smallest quantity of a substance capable of existing in a free state.

**18. What is meant by combination in definite and multiple proportions? July 1845.**

The law of definite or of constant proportions may be thus expressed:—

*The same substance always consists of the same elements united in the same proportions.*

Thus, for example, water is composed of hydrogen and oxygen, in the proportion of two atoms of hydrogen to one of oxygen. This by weight makes 2 grammes or grains, &c., of hydrogen to 16 grammes or grains, &c., of oxygen, making 18 grammes or grains, &c., of water; and these elements are found in water invariably in the same identical proportions and in no other. Again, common salt always contains 35½ parts by weight of chlorine to 23 parts by weight of sodium; and ver-

million always contains 32 parts by weight of sulphur to 200 of mercury.

**19.** Illustrate the law of multiple proportions by a series of examples, including compounds of carbon with oxygen, carbon with hydrogen, sulphur with oxygen, nitrogen with oxygen. *June 1865.*

State the doctrine of multiple proportions, and explain it by examples. *July 1844.*

*When a body is capable of combining with another in several proportions, these several proportions bear a simple relation to each other.*

(1) Thus, take for example the compounds of carbon with oxygen:—

Carbonic oxide,

$\text{CO} \dots 12 \text{ of C with } 16 \times 1 \text{ of O.}$

Carbonic dioxide,

$\text{CO}_2 \dots 12 \text{ of C with } 16 \times 2, \text{ or } 32 \text{ of O.}$

Thus the oxygen in the  $\text{CO}$  and  $\text{CO}_2$  stand to one another as 1 : 2.

(2) The compounds of carbon with hydrogen, limiting them to two:—

Light carburetted hydrogen,

$\text{CH}_4 \dots 4 \text{ of H with } 12 \times 1 \text{ of C.}$

Heavy carburetted hydrogen,

$\text{C}_2\text{H}_4 \dots 4 \text{ of H with } 12 \times 2, \text{ or } 24 \text{ of C.}$

Thus the carbon in the  $\text{CH}_4$  and  $\text{C}_2\text{H}_4$  stand to one another as 1 : 2.

(3) The compounds of sulphur with oxygen:—

Sulphurous dioxide,

$\text{SO}_2 \dots 32 \text{ of S with } 16 \times 2, \text{ or } 32 \text{ of O.}$

Sulphuric trioxide,

$\text{SO}_3 \dots 32 \text{ of S with } 16 \times 3, \text{ or } 48 \text{ of O.}$

Thus the oxygen in  $\text{SO}_2$  and  $\text{SO}_3$  stand to one another as 2 : 3.

(4) The compounds of **nitrogen** with **oxygen** :—

Nitrous oxide,

$\text{N}_2\text{O}$  . . 28 of N with  $16 \times 1$  of O.

Nitric oxide,

$\text{N}_2\text{O}_2$  . . 28 of N with  $16 \times 2$ , or 32 of O.

Nitric trioxide,

$\text{N}_2\text{O}_3$  . . 28 of N with  $16 \times 3$ , or 48 of O.

Nitric tetroxide,

$\text{N}_2\text{O}_4$  . . 28 of N with  $16 \times 4$ , or 64 of O.

Nitric pentoxide,

$\text{N}_2\text{O}_5$  . . 28 of N with  $16 \times 5$ , or 80 of O.

Thus the oxygen of  $\text{N}_2\text{O}$ ,  $\text{N}_2\text{O}_2$ ,  $\text{N}_2\text{O}_3$ ,  $\text{N}_2\text{O}_4$ ,  $\text{N}_2\text{O}_5$ , stand to each other as 1 : 2 : 3 : 4 : 5.

**20.** Explain the laws of combination in equivalent and multiple proportions. *July 1855.*

The law of multiple proportions has been expressed and explained in the previous number.

The law of equivalent proportions may be expressed thus :—

*If two bodies combine with a third, the proportions in which they combine with that third body are multiples of the proportions in which they may combine with each other.*

That is to say, supposing a certain weight of a body A combine with a certain weight of the bodies B, C, D; then if B, C, D unite with each other, they will do so in the same proportion by weight as that in which they combine with A, or in some multiple of that proportion.

Thus 1 part of hydrogen combines with 32 of sulphur and with 16 of oxygen : therefore when sulphur and oxygen combine, it will be in the proportion of 32 : 16, or in some multiple of those numbers.

**21.\*** Express the law of molecular or combining weights, and give an example.

*The molecular or combining weight of a compound is the sum of the combining weights of the components.*

Thus the combining weight of hydric chloride is 36.5, which is the sum of the combining weight of hydrogen 1, and that of chlorine 35.5.

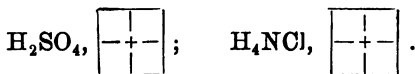
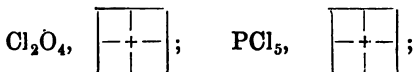
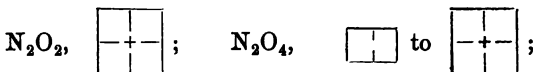
**22.** Explain what is understood by the theory of volumes. Jan. 1860.

A molecule of any substance, in the state of gas or vapour, occupies the same volume as a molecule, or two atoms, of hydrogen does. This is generally expressed by saying that *the molecular volume of a gas is 2 vols., or*

	+	

.

The chief exceptions are—



**23.** What is meant by the expression atomic weight? July 1856.

The atomic weights of the elements are the *relative* weights in which the elements combine with one another, whether according to those actual proportions, or multiples of those proportions. The atomic weights are generally referred to hydrogen, which as standard is

assumed to have the atomic weight of 1. The numbers may stand for grammes or grains, or any other actual weight, as circumstances require.

**24.** Give the atomic weights of oxygen, chlorine, iodine, hydrogen, nitrogen, and carbon, according to the *hydrogen* and *oxygen* scales. *July 1858.*

	Hydrogen scale.	Oxygen scale.
Oxygen,	16	100
Chlorine,	35.5	442.65
Iodine,	127	1579.5
Hydrogen,	1	12.48
Nitrogen,	14	177.04
Carbon,	12	75.4

**25.** Explain what is meant by the term **molecular weight**. One molecule of ammonia consisting of one atom of nitrogen and three atoms of hydrogen, what is the molecular weight of ammonia? *June 1872.*

By **molecular weight** is meant the sum of the atomic weights of the elements of a molecule.

The molecular weight of ammonia ( $\text{NH}_3$ ) is  $14 + 3 = 17$ .

**26.** Give the molecular weights of **common salt**, **iodide of potassium**, **carbonic acid**, and **nitrate of silver**. (The following atomic weights may be adopted: —Chlorine, 35.5; sodium, 23; iodine, 127; potassium, 39; carbon, 12; oxygen, 16; nitrogen, 14; silver, 108.) *Jan. 1865.*

Common salt ( $\text{NaCl}$ )	has for molecular weight	58.5
Iodide of potassium ( $\text{KI}$ )	" "	166
Carbonic acid ( $\text{CO}_2$ )	" "	44
Nitrate of silver ( $\text{AgNO}_3$ )	" "	170

**27.** Explain, with reference to examples, the meaning of the term **chemical equivalent**. *July 1844.*

**Chemical equivalent** is a definite weight of one element capable of replacing a definite weight of another element. Since 35.5 parts by weight of chlorine combine with one part by weight of hydrogen to form hydric chloride, 35.5 parts by weight of chlorine are said *to be equivalent* to 1 part by weight of hydrogen. Also, since 2 parts by weight of hydrogen combine with 16 parts by weight of oxygen to form water, 8 parts by weight of oxygen are said *to be equivalent* to 1 part by weight of hydrogen. So also, as 35.5 parts by weight of chlorine are equivalent to 1 part by weight of hydrogen, they are by deduction equivalent to 8 parts by weight of oxygen.

**28.** Explain what is meant by **combining proportions, equivalents**,<sup>1</sup> or **atomic numbers**. *July 1849.*

The examiner takes these three expressions as synonymous. They refer to the proportions, or to the multiples of them, in which all the bodies combine among themselves. For example, the atomic weight of hydrogen is 1, that of oxygen 16, that of nitrogen 14, that of potassium 39: therefore, when these bodies form compounds among themselves, they will always do so in some simple multiples of 1, 16, 14, 39.

**29.** What is the composition of the following substances:—**Air, water, silica, marble, ammonia, marsh gas, and black lead or plumbago?** Give the names of

<sup>1</sup> The term *equivalent* was formerly used as synonymous with 'atomic weight;' but at present the term is scarcely used, and in its present meaning it signifies the atomic weight divided by the atomicity.

the substances represented by the following formulæ :—  
CO, NO, SO<sub>2</sub>, N<sub>2</sub>O<sub>3</sub>, PH<sub>3</sub>, and NH<sub>4</sub>Cl. *Jan.* 1879.

**Air**, a mixture chiefly of oxygen, nitrogen, and carbonic dioxide.

**Water** (OH<sub>2</sub>), a compound of oxygen and hydrogen.

**Silica** (SiO<sub>2</sub>), a compound of silicon and oxygen.

**Marble** (CaCO<sub>3</sub>), a compound of calcium, carbon, and oxygen.

**Ammonia** (NH<sub>3</sub>), a compound of nitrogen and hydrogen.

**Marsh gas** (CH<sub>4</sub>), a compound of carbon and hydrogen.

**Black lead** or plumbago is an allotropic modification of carbon.

The name of CO is carbonic oxide, or oxide of carbon.

„ NO is nitric oxide (N<sub>2</sub>O<sub>2</sub>).

„ SO<sub>2</sub> is sulphuric dioxide, or sulphurous anhydride.

„ N<sub>2</sub>O<sub>3</sub> is nitric trioxide, or nitrous anhydride.

„ PH<sub>3</sub> is hydric phosphide, or phosphuretted hydrogen.

„ NH<sub>4</sub>Cl is ammoniac chloride.

**30.** Write the names of the following compounds :—  
CO, CO<sub>2</sub>, N<sub>2</sub>O, N<sub>2</sub>O<sub>3</sub>, N<sub>2</sub>O<sub>5</sub>, CH<sub>4</sub>, C<sub>2</sub>H<sub>4</sub>, SO<sub>2</sub>, SO<sub>3</sub>, and H<sub>2</sub>S. *Jan.* 1881.

The name of CO is carbonic oxide.

„ CO<sub>2</sub> is carbonic dioxide, or carbonic acid.

„ N<sub>2</sub>O is nitrous oxide (laughing gas).

„ N<sub>2</sub>O<sub>3</sub> is nitric trioxide, or nitrous anhydride.

The name of  $N_2O_5$  is nitric pentoxide, or nitric anhydride.

„  $CH_4$  is light carburetted hydrogen (methyl hydride or marsh gas).

„  $C_2H_4$  is heavy carburetted hydrogen (ethylene, or olefiant gas).

„  $SO_2$  is sulphuric dioxide, or sulphurous anhydride.

„  $SO_3$  is sulphuric trioxide, or sulphuric anhydride.

„  $H_2S$  is hydric sulphide, or sulphuretted hydrogen.

**31.** Calculate the molecular weights and percentage composition of the salts having the formula  $CaSO_4 + 2OH_2$  and  $BaCl_2 + 2OH_2$ ; and give the chemical characters by which they can be identified, and the names of the salts. *Jan.* 1860.

$CaSO_4 + 2OH_2$  is called calcic sulphate.

$$Ca = 40 \dots \frac{40 \times 100}{172} = 23.26$$

$$S = 32 \dots \frac{32 \times 100}{172} = 18.60$$

$$O_4 = 64 \dots \frac{64 \times 100}{172} = 37.21$$

$$(2OH_2) = \frac{36}{172} \dots \frac{36 \times 100}{172} = \frac{20.93}{100.00}$$

Molec. weight = 172

$BaCl_2 + 2OH_2$  is called baric chloride.

$$Ba = 137 \dots \frac{137 \times 100}{244} = 56.15$$

$$Cl_2 = 71 \dots \frac{71 \times 100}{244} = 29.10$$

$$(2OH_2) = \frac{36}{244} \dots \frac{36 \times 100}{244} = \frac{14.75}{100.00}$$

Molec. weight = 244

In order to identify these two salts, dissolve both in water; then add to both solutions a few drops of baric chloride. A white precipitate is formed in the solution of calcic sulphate, but not in the baric chloride. Then add to the solutions a few drops of argentic nitrate. A white precipitate is formed in the solution of baric chloride, but not in that of calcic sulphate.

**32.** What are the proportions by weight of the constituent elements of the following compounds:—Marsh gas, olefant gas, carbonic acid, and water? *June 1869.*

**Marsh gas** ( $\text{CH}_4$ ). The proportions are 12 of carbon and 4 of hydrogen.

**Olefant gas** ( $\text{C}_2\text{H}_4$ ). Proportions, 24 of carbon and 4 of hydrogen.

**Carbonic acid** ( $\text{CO}_2$ ). Proportions, 12 of carbon and 32 of oxygen.

**Water** ( $\text{OH}_2$ ). Proportions, 16 of oxygen and 2 of hydrogen.

**33.** Define the chemical term acid. *June 1881.*

Strictly speaking, an acid is a body containing hydrogen replaceable by a metal, when that metal is presented to it in the form of a hydrate; e.g. hydric sulphate ( $\text{H}_2\text{SO}_4$ ), hydric chloride ( $\text{HCl}$ ).

When the water ( $\text{OH}_2$ ) has been abstracted, the body often retains the name of an acid; but it is better to prefix the term *anhydrous*, which means *without water*; e.g.  $\text{SO}_2$ ,  $\text{SO}_3$ ,  $\text{N}_2\text{O}_5$ .

**34.** Define the chemical term base. *June 1881.*

A base is a certain compound of a metal with oxygen, as  $\text{Na}_2\text{O}$ ,  $\text{CaO}$ ,  $\text{Fe}_2\text{O}_3$ ; with hydroxyl ( $\text{OH}$ ), as  $\text{KHO}$ ,  $\text{BaH}_2\text{O}_2$ ,  $\text{Fe}_2\text{H}_6\text{O}_6$ ; or with nitrogen, phosphorus, &c., as  $\text{NH}_3$ ,  $\text{PH}_3$ .

**35.** What are the **distinctive properties** of the two classes, acids and alkaline oxides or bases? What is the **nature** of a salt? *July 1846.*

What is the distinction between an **alkali** and an **acid**? What is meant by the term **salt**? *July 1860.*

Define the chemical term **salt**. *June 1881.*

The **distinctive properties** of acids and alkaline oxides or bases are:—

1st. The first turn blue litmus red, and the latter turn red litmus blue.

2nd. They combine together to form salts, generally with the elimination of water.

A **salt** may therefore be defined as *an acid in which the hydrogen has been partly or wholly replaced by a metal*. If the hydrogen has been only partly removed, the salt is said to be *acid*; if wholly, it is said to be *neutral*. If more base is present than is necessary to neutralise the acid, the salt is said to be *basic*.

**36.** What is meant by the expression of the **neutralisation** of an acid by an alkali? What is the **result** of such neutralisation? *July 1844.*

It means that the acid and the alkali have both lost their characteristic properties, that is to say, that they are **without action upon litmus paper**.<sup>1</sup> The result of such neutralisation is a **neutral salt**.

**37.** What class of bodies do we call **oxides**? Name some oxides of an **acid nature** and some **basic oxides**. *June 1867.*

*Oxides are a class of bodies resulting from the combination of oxygen with other elements.*

<sup>1</sup> This is not always true. Some chemically neutral salts are acid, some are basic to litmus; some chemically acid salts are basic to litmus, and *vice versa*.

Oxides of an acid nature are—nitric pentoxide,  $N_2O_5$ ; sulphurous dioxide,  $SO_2$ ; sulphuric trioxide,  $SO_3$ , &c.

Oxides of a basic nature are—potassic oxide,  $K_2O$ ; sodic oxide,  $Na_2O$ ; calcic oxide,  $CaO$ , &c.

**38.** Two liquids are given, one containing an acid and the other a base. Describe the experiments you would perform in order to ascertain which of the two liquids contains the acid. *Jan. 1868.*

**39.** Two oxides are given to you, one an acid, the other a base. Explain how you would determine which of the two is the acid. *Jan. 1860—June 1874.*

The term acid is, I presume, used here to mean an acid oxide or an *anhydride*. First, then, I should add distilled water to both, and afterwards I should dip into each vessel a strip of blue litmus paper. The vessel in which the blue litmus turns red, contains the acid, and the other the base. Again, I should add a little of each solution to an alkaline solution: the one that neutralises that solution is the acid; then I should add a little of each solution to an acid solution: the one that neutralises that solution is the base.

Finally, the acid poured over a carbonate, whether the carbonate be in solution or not, causes a great effervescence, which would not be caused by an oxide.

**40.** Give an example of an acid, a base, and a salt, and explain how you would ascertain to which of these classes a given substance belongs. *June 1866—June 1881.*

1st. Example of an acid—hydric sulphate,  $H_2SO_4$ .

2nd. „ a base—potassic oxide,  $K_2O$ .

3rd. „ a salt—potassic sulphate,  $K_2SO_4$ .

I should first dissolve them in water, if already they are not so. Then a little blue litmus paper dipped in the first solution would become red, and would again become blue if dipped in the second. If dipped in the third solution, it would remain unaffected.

**41.** What is meant by an **hydrate**? Exemplify the difference between water of composition and water of crystallisation. *July 1863.*

Oxides combined with water form hydrates ( $\text{KHO}$ ,  $\text{NaHO}$ ). The water there combined is called **water of hydration**.

Some salts contain water chemically combined as essential to their constitution ( $\text{CaH}_2\text{SO}_5$ ;  $\text{CaH}_4\text{SO}_6$ ). This is called **water of composition**.

Other salts contain water which is not necessary to their composition, but only to their crystalline form ( $\text{KAlS}_2\text{O}_8 + 12\text{OH}_2 = \text{alum}$ ). This water is called **water of crystallisation**.

Water of crystallisation is driven off by a temperature of about  $100^\circ \text{C}$ ., which is not the case with water of composition.

**42.** Indicate the distinctive characters of **alkalies**, **alkaline earths**, and **earths**, appending a tabular list of the different species under each class. *Jan. 1860.*

The **alkalies**<sup>1</sup> are soft, easily fusible, volatile at higher temperature, combine very energetically with oxygen, decompose water at all temperatures, and form strong basic oxides very soluble in water.

The **alkaline earths** are similar to the alkaline metals, except that they are less soluble in water.

The **earths** are not soluble at all in water.

<sup>1</sup> The *oxides* and *hydrates* are the alkalies, &c. The *metals* in them are termed metals of the alkalies, alkaline earths, and earths.

*Tabular List.*

## Alkali metals

$H_3N$   
 $KHO$   
 $NaHO$   
 $LiHO$

## Alkaline earths

$BaH_2O_2$  or  $BaO$   
 $SrH_2O_2$  or  $SrO$   
 $CaH_2O_2$  or  $CaO$

## Earth

$Al_2O_3$

**43.** Explain the nature of oxidation and the nomenclature of the oxides. *July 1857.*

When metals and certain other bodies are placed in the presence of oxygen, they combine, forming a class of salts called oxides. This takes place in the case of some, such as potassium and sodium, by exposure to the air at ordinary temperatures; in the case of others, as zinc, iron, and lead, when moisture is present or when heated; with others, as in the case of antimony and mercury, under the influence of heat. Most metallic oxides are reduced by hydrogen and by carbon.

To designate the oxides, it is best to give first the metal or the non-metal, followed by the word *oxide*. If it is required to express the exact number of atoms of oxygen present, the word oxide has the syllables *mono*, *di* or *bi*, *tri* or *ter*, *tetra*, *penta* prefixed. Some oxides are acid, and are termed *anhydrides*; others are neutral; and again others are basic.

**44.** How are elements and compounds denoted by symbols and chemical formulæ? *July 1849.*

The elements are denoted by the first or first and second letters of their name. In a few cases the initial of the Latin name is taken. Thus H, O, Na, K stand for hydrogen, oxygen, sodium (*natrium*), and potassium (*kalium*).

Compounds are denoted by the symbols of their

**component elements**; and if there be present more than one atom of any component element, a small figure indicating the number of atoms present is placed below to the right of the symbol of that element. Thus  $\text{H}_2\text{SO}_4$  is the chemical formula for hydric sulphate, and denotes that there are present 2 atoms of hydrogen, 1 of sulphur, and 4 of oxygen."

**45.** Write in **symbols** the following compounds:—Water, sulphuric acid, nitric acid, nitrous oxide, sulphuretted hydrogen. *Jan.* 1865.

Water,  $\text{OH}_2$ ; sulphuric acid,  $\text{H}_2\text{SO}_4$ ; nitric acid,  $\text{HNO}_3$ ; nitrous oxide,  $\text{N}_2\text{O}$ ; sulphuretted hydrogen,  $\text{H}_2\text{S}$ .

**46.** Explain fully the meaning of the following symbols:— $\text{O}_2$ ,  $\text{H}_2$ ,  $\text{Cl}_2$ ,  $\text{Br}_2$ ,  $\text{I}_2$ , C,  $\text{N}_3$ , S, P,  $\text{CO}_2$ ,  $\text{SO}_3$ ,  $\text{OH}_2$ , and  $\text{NH}_3$ . *June* 1866.

$\text{O}_2$  means a molecule or two atoms of free oxygen.

$\text{H}_2$  means a molecule or two atoms of free hydrogen.

$\text{Cl}_2$  means a molecule or two atoms of free chlorine.

$\text{Br}_2$  means a molecule or two atoms of free bromine.

$\text{I}_2$  means a molecule or two atoms of free iodine.

C means one atom of free carbon.

$\text{N}_2$  means a molecule or two atoms of free nitrogen.

S means one atom of free sulphur.

P means one atom of free phosphorus.

$\text{CO}_2$  means one molecule of carbonic dioxide (carbonic acid).

$\text{SO}_3$ ,  $\text{OH}_2$  ( $\text{H}_2\text{SO}_4$ ) means one molecule of hydric sulphate (sulphuric acid).

$\text{NH}_3$  means one molecule of ammonia.

**47.** Give the **chemical formulæ** for common salt, saltpetre, iron, and copper. *July* 1857.

Common salt,  $\text{NaCl}$ ; saltpetre,  $\text{KNO}_3$ ; iron,  $\text{Fe}$ ; copper,  $\text{Cu}$ .

**48.** Give the chemical symbols and formulæ for gold, silver, lead, nitrate of silver, nitrate of baryta, caustic soda. *July 1858.*

Gold,  $\text{Au}$ ; silver,  $\text{Ag}$ ; lead,  $\text{Pb}$ ; argentic nitrate (nitrate of silver),  $\text{AgNO}_3$ ; baric nitrate (nitrate of baryta),  $\text{Ba}(\text{NO}_3)_2$  or  $\text{BaN}_2\text{O}_6$ ; sodic hydrate (caustic soda),  $\text{NaHO}$ .

**49.** Give the composition and systematic designation of each of the following salts:—Common salt, alum, green vitriol or copperas, gypsum, nitre, limestone, and fluor spar. *July 1855.*

Common salt, sodic chloride,  $\text{NaCl}$ .

Alum, aluminic potassic sulphate,  $\text{AlK}(\text{SO}_4)_2 + 12\text{OH}_2$ .

Green vitriol, ferrous sulphate,  $\text{FeSO}_4 + 7\text{OH}_2$ .

Gypsum, calcic sulphate,  $\text{CaSO}_4 + 2\text{OH}_2$ .

Nitre, potassic nitrate,  $\text{KNO}_3$ .

Limestone, calcic carbonate,  $\text{CaCO}_3$ .

Fluor spar, calcic fluoride,  $\text{CaF}_2$ .

The composition of each salt is sufficiently expressed through its formula.

**50.** Give the formulæ of the following substances:—Water, ammonia, silica, carbonic acid, sulphuric acid, marsh gas, and phosphuretted hydrogen. *Jan. 1869.*

Water,  $\text{OH}_2$ ; ammonia,  $\text{H}_3\text{N}$ ; silica,  $\text{SiO}_2$ ; carbonic acid,  $\text{CO}_2$ ; sulphuric acid,  $\text{H}_2\text{SO}_4$ ; marsh gas,  $\text{CH}_4$ ; phosphuretted hydrogen,  $\text{PH}_3$ .

**51.** Give the symbols of the following elements and compounds:—Hydrogen, nitrogen, nitrous acid, carbon,

marsh gas, chlorine, bromine, phosphorus, phosphoric acid, and silicic acid. *June 1867.*

Hydrogen = H, nitrogen = N, nitrous acid =  $\text{N}_2\text{O}_3$ , carbon = C, marsh gas =  $\text{CH}_4$ , chlorine = Cl, bromine = Br, phosphorus = P, phosphoric acid =  $\text{H}_3\text{PO}_4$  (or  $\text{P}_2\text{O}_5$ ), silicic acid =  $\text{SiO}_2$ .

**52.** Give the atomic constitution and formulæ of alum, sulphate of magnesia, sulphate of soda, and calomel. *July 1856.*

Alum,  $\text{AlK}(\text{SO}_4)_2 + 12 \text{OH}_2$ , is constituted of 1 atom of aluminium, 1 of potassium, 2 of sulphur, and 8 of oxygen, crystallised with 12 molecules of water of crystallisation.

Sulphate of magnesia,  $\text{MgSO}_4 + 7 \text{OH}_2$ , is constituted of 1 atom of magnesium, 1 of sulphur, and 4 of oxygen, crystallised with 7 molecules of water of crystallisation.

Sulphate of soda,  $\text{Na}_2\text{SO}_4 + 10 \text{OH}_2$ , is constituted of 2 atoms of sodium, 1 of sulphur, and 4 of oxygen, crystallised with 10 molecules of water of crystallisation.

Calomel (mercurous chloride),  $\text{Hg}_2\text{Cl}_2$ , is constituted of 2 atoms of mercury and 2 atoms of chlorine.

**53.** Give the chemical names of the salts having the formulæ  $\text{KCl}$  and  $\text{Na}_2\text{O} \cdot \text{CO}_2$ , and detail the means by which they can be discriminated. *July 1859.*

$\text{KCl}$  = potassic chloride, and  $\text{Na}_2\text{O} \cdot \text{CO}_2$  (or  $\text{Na}_2\text{CO}_3$ ) = sodic carbonate or disodic carbonate.

If any acid, say hydric sulphate, be poured into a solution of a carbonate, an effervescence takes place, and the carbonic dioxide is expelled, causing lime-water to become turbid. This does not take place with potassic chloride when so treated.

On the other hand, add to the solution of potassic chloride a few drops of hydric nitrate and argentic nitrate. A white precipitate of argentic chloride is formed, which result is not seen if sodic carbonate be treated in like manner.

**54.** Give the formulæ of the following substances :—  
Water, ammonia, silica, carbonic acid, sulphuric acid, marsh gas, and phosphuretted hydrogen. *Jan. 1869.*

Water =  $\text{OH}_2$ , ammonia =  $\text{NH}_3$ , silica =  $\text{SiO}_2$ , carbonic acid =  $\text{CO}_2$ , sulphuric acid =  $\text{H}_2\text{SO}_4$ , marsh gas =  $\text{CH}_4$ , phosphuretted hydrogen =  $\text{PH}_3$ .

**55.** Give the formulæ of potassic nitrate and potassic nitrite. *June 1880.*

Potassic nitrate has for formula  $\text{KNO}_3$ , potassic nitrite  $\text{KNO}_2$ .

**56.** What is meant by the term crystal? Describe some of the processes by which crystals may be formed. *July 1860.*

A crystal is the regular geometrical form which certain solid bodies assume when placed in favourable circumstances, the form being bounded by planes, which are inclined at angles to one another under certain laws.

As an example of crystallisation melt sulphur, and after it has cooled and formed a solid crust at its surface, break the crust and pour off the still liquid portion of the sulphur, when a beautiful crystallisation will be found to have taken place.

Crystals may be formed by the process of fusion, which consists in melting the substances so as to give to the particles freedom of motion among each other, as mentioned above in the case of sulphur; by sublimation,

which consists in heating a body till its particles rise in vapour, as is the case with sulphur raised to a temperature of  $490^{\circ}\text{C}$ .; and, lastly, *by solution*, which consists in dissolving the substance and evaporating it either by heat or by exposure to the air, as is the case with sulphur dissolved in carbonic disulphide.<sup>1</sup>

**57.** Explain what is meant by **dimorphism**, and give examples of dimorphous bodies. *Jan. 1860.*

*A body that crystallises into two systems is said to be dimorphous*, from two Greek words signifying two-shaped.

Sulphur is dimorphous, because when melted it crystallises in a shape belonging to the oblique prismatic system; when dissolved it crystallises in a shape belonging to the right prismatic system. Carbon also is dimorphous.

**58.** What are the acid solvents of mercury, silver, gold, and platinum? *July 1853.*

The solvent of mercury (Hg) and silver (Ag) is hydric nitrate.

The solvent of gold (Au) and platinum (Pt) is aqua regia, which is a mixture of hydric nitrate and hydric chloride.

<sup>1</sup> Note that the crystals are not formed during fusion, evaporation, or solution, but during solidification, condensation, and deposition.



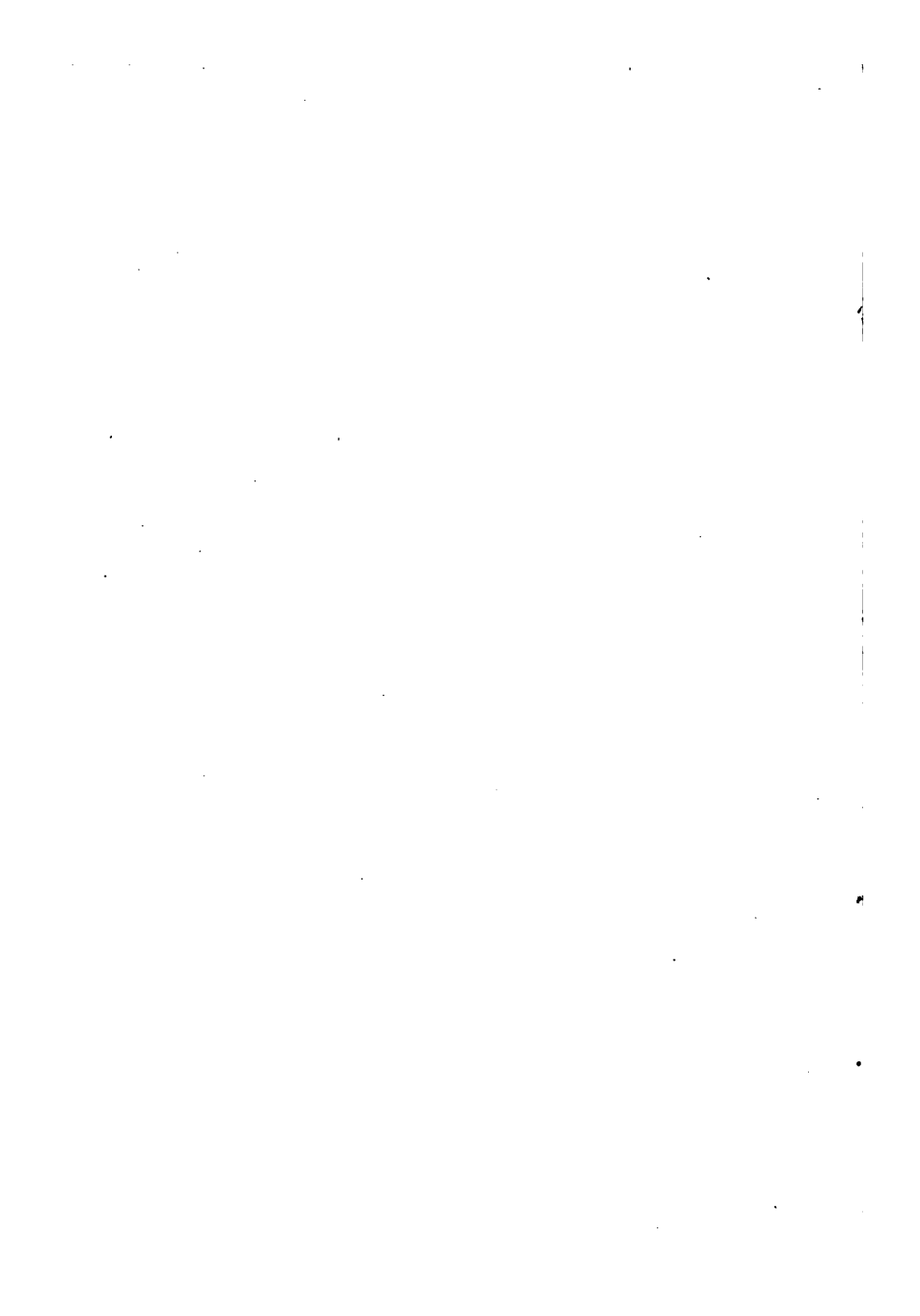
## CHAPTER I.

### OXYGEN (O).

(Dyad, as in HCl.)

$$\frac{(\text{O}_2) \text{ Molecular weight, } 32.}{\text{Molecular volume, } \boxed{\phantom{00}}} = 16 \text{ sp. gr.}$$

Or 16 grammes of O occupy a volume of 11.2 litres.  
16 grains of O occupy a volume of 44.4 c. inches.



## OXYGEN.

**59.** Describe some of the most important natural substances in which oxygen is contained, and explain the preparation of the gas from the black oxide of manganese. *June 1865.*

Firstly,—oxygen is found in a free state in the atmosphere, of whose volume it forms about one-fifth. Air is a mixture of gases, chiefly nitrogen and oxygen. It is perfectly transparent and without smell.

Again, water is another important natural substance containing oxygen. Water at the ordinary temperature is liquid, but easily assumes the solid or gaseous form. When seen in small quantities it is colourless, but when observed in large quantities it has a bluish-green colour. When pure it is tasteless. It dissolves with great readiness very many substances.

Oxygen also forms part of many compounds, both animal and vegetable, as wood, sugar, and the flesh and fat of animals. It is so widely distributed in nature that it is said to constitute one-half of the weight of the earth. It also forms the greatest part by weight of water.

When oxygen is wanted in great quantities, it is usual to prepare it from the black binoxide or dioxide manganic dioxide ( $\text{MnO}_2$ ). The mineral manganese is strongly heated in an iron mercury bottle, fitted with

an iron exit-tube. Yet however strongly the mineral be heated, only one-third of its oxygen is given off.

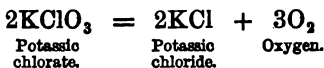
The equation expressing the reaction is



**60.** Describe the preparation of oxygen from potassic chlorate. Give symbols of the decomposition. *June 1864—June 1867—Jan. 1881.*

The potassic chlorate is first powdered and dried, in order to prevent decrepitation and deposition of moisture in the tube, placed in a test-tube fitted with a cork and exit-tube, and carefully heated. The salt first melts and appears to boil from the evolution of oxygen. A high temperature is required to obtain the maximum of oxygen, when potassic chloride remains in the tube.

The change is represented by the following equation :—



It is usual to add to the potassic chlorate about one-fourth its weight of dry powdered black oxide of manganese (manganic dioxide); the two substances are well mixed, placed in the test-tube, which is held horizontally, and then heated. Under these circumstances the oxygen is produced at a lower temperature, but is slightly contaminated with chlorine. The black oxide of manganese remains unchanged.

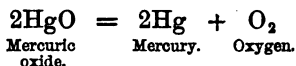
**61.** Describe and explain the preparation of oxygen from mercuric oxide. *June 1872.*

By heating dried mercuric oxide ( $\text{HgO}$ ), at first carefully, in a strong glass tube. After a short time minute globules of mercury will collect at the upper

part of the test-tube, showing thereby that the decomposition has commenced.

On continuing to heat the tube, **oxygen** is given off and may be collected at the pneumatic trough, and globules of mercury are formed in the tube, while the mercuric oxide gradually disappears, thus showing that the application of heat resolves the **mercuric oxide** into its elements, mercury and oxygen.

The reaction may be represented by the following equation:—



**62.** How did Lavoisier show the **presence of oxygen** in air? *June* 1866.

Describe the experiment by which Lavoisier proved air to consist of oxygen and nitrogen. *June* 1869.

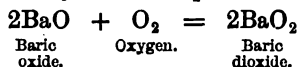
Lavoisier originally kept mercury (Hg) for many days at a temperature near its boiling point, in contact with a known volume of air. At first absorption took place, but after a time ceased, while during the absorption red scales were formed on the surface of the metal. One-fifth of the air was absorbed, while the remainder was no longer able to support combustion. Lavoisier afterwards heated the red scales at a much higher temperature than that at which they were formed, and thereby resolved them into quicksilver (Hg) and a colourless gas which had the power of supporting combustion more brilliantly than air, and which, when added to the gas left in the first part of the experiment, restored to it all its original properties. He named the gas which so strongly supported combustion **oxygen**, and the compound which it formed with mercury, mercuric oxide.

**63.** By what means can **oxygen** be separated from atmospheric air and obtained in a pure form? *June 1864.*

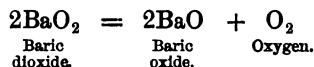
One method would be to repeat the experiment by which Lavoisier proved the presence of oxygen in the composition of the air. (For the description of this experiment see No. 62.)

A second method<sup>1</sup> would be to pass a current of air over very strongly heated baryta (BaO), which, by absorbing one atom of oxygen, is changed into baric dioxide (BaO<sub>2</sub>). This last compound when heated to a still higher temperature is changed back into baryta, setting free the atom of oxygen which it had previously absorbed, and thus the operation may be continued; the same quantity of baryta serving for an indefinite number of times.

The reaction may be thus represented:—



and



**64.** Describe two of the best methods of obtaining **oxygen**. How much heavier is it than hydrogen? *July 1851—Jan. 1862—Jan. 1863.*

The two best methods of obtaining oxygen gas are to decompose potassic chlorate (KClO<sub>3</sub>) in the presence of dioxide of manganese (MnO<sub>2</sub>), and to submit to a great heat the mineral **black oxide of manganese**.

<sup>1</sup> 'Mr. Brin informs us that he has greatly improved the manufacture of oxygen by Boussingault's process of peroxidising and reoxidising barium. This material, after being used 400 times, was found not to be deteriorated. Mr. Brin expects to be able to supply oxygen on a large scale at 2 to 3 pence per 35 cubic feet.'—*Athen.*, April 1, 1882.

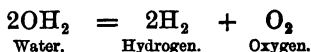
These two methods have been described in Nos. 59 and 60.

**Oxygen is sixteen times heavier than hydrogen.** In order to collect the gas, the lower end of the bent tube in communication with the flask dips under the surface of the water in a pneumatic trough; and the gas, on being evolved, bubbles out from the end of the tube, and is collected in bottles filled with water and placed with their mouths downward in the trough.

**65.** Describe by equations as many processes as you know for the preparation of **oxygen gas**. *July 1854—Jan. 1870.*

Explain by chemical formulæ three distinct methods by which **oxygen gas** can be prepared. *Jan. 1877.*

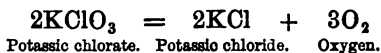
1st. By electrolysis of water:—



2nd. From mercuric oxide:—



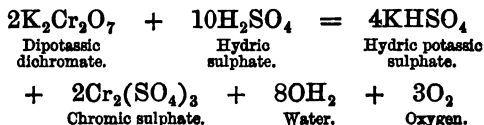
3rd. From potassic chlorate:—



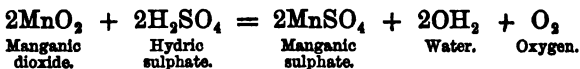
4th. From manganic dioxide:—



5th. From potassic dichromate and hydric sulphate:—



6th. From manganic dioxide and hydric sulphate:—



**66.** Give an account of the properties of one of the principal constituents of the atmosphere—namely, oxygen. *July 1850:*

Describe the properties of oxygen gas. *July 1846—  
July 1854.*

Oxygen is a colourless, invisible gas, possessing neither taste nor smell. It exists free in the atmosphere, of which it constitutes about one-fifth in bulk. It forms eight-ninths by weight of water and nearly half the weight of the solid earth. It was till lately believed that it was impossible to reduce it to the liquid state, but a Swiss chemist has recently shown that notion to be false. Oxygen is a little heavier than air. Its specific gravity compared with air is 1.10563. Oxygen is necessary to animals in breathing and is essential in all cases of ordinary combustion; it is, therefore, said to be a supporter of combustion. Bodies which burn in the air burn in oxygen with greatly increased splendour. If a taper be blown out and introduced into the gas while the wick remains red hot, it is instantly re-kindled. This effect is highly characteristic of oxygen, there being but one other gas, nitrous oxide ( $\text{N}_2\text{O}$ ), which possesses the same property. Lastly, all the elements, with the exception of fluorine, form compounds containing oxygen.

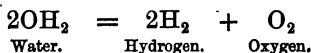
**67.** How many cubic centimetres of oxygen are contained in 100 cubic centimetres of air? and how many cubic centimetres of hydrogen would be burned by this quantity of oxygen? *June 1869.*

It is found from careful analysis of air that in 100 parts of air there are 21 parts by volume of oxygen and 79 parts by volume of nitrogen. Hence in 100 cubic centimetres of air there are 21 c.c. of oxygen.

With regard to the second part of the question, we know that hydrogen is completely burned by oxygen in the proportion by volume of 2 to 1. Hence to burn 21 c.c. of hydrogen 42 c.c. of oxygen will be required.

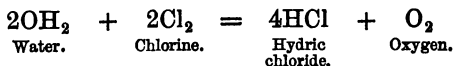
**68.** How would you extract oxygen from water? Explain your process. *Jan. 1873.*

Water is decomposed into oxygen and hydrogen by electricity. The equation for the reaction would be :—



For the explanation of the process see No. 99, in Chapter III.

Also if a stream of chlorine be passed through a flask of boiling water, it will escape by the exit tube saturated with vapour of water. If the exit tube be connected with a glass tube filled with fragments of glass or pumice, heated to redness by a furnace, a chemical change takes place, by which a mixture of oxygen and hydric chloride is produced; and if this mixture passes through the water of the pneumatic trough, the hydric chloride is dissolved and the oxygen may be collected. The following represents the reaction :—



**69.** How is oxygen distinguished from nitrogen and from nitrous oxide? *June 1863.*

A given sample of gas is found to have the property of kindling a glowing splint of wood. Enumerate the

reactions by which you would decide whether it consists of oxygen or nitrous oxide. *Jan.* 1870.

How would you distinguish nitrous oxide from oxygen? *June* 1874.

Oxygen may be instantly distinguished from nitrogen by lowering into the vessel containing the gas a freshly extinguished taper. If the vessel contains *oxygen*, the taper will be instantly re-kindled, whereas if the gas be *nitrogen* the red-hot wick, or even a lighted taper, will be at once extinguished.

Now this same test will be of no avail with regard to nitrous oxide ( $N_2O$ ), because oxygen and nitrous oxide have in common the property of strongly supporting combustion. But nitric oxide forms brown fumes with free oxygen, and not with any other gas. Therefore, to distinguish oxygen from nitrous oxide, pass into both a little nitric oxide. It will produce brown fumes in the *oxygen* and not in the *nitrous oxide*.

Also a solution of potassic pyrogallate absorbs free oxygen, becoming black at the same time. If, therefore, a few drops of the solution of potassic pyrogallate be shaken in jars of the two gases, it will become black in the *oxygen* and not in the *nitrous oxide*.

**70.** How much oxygen is contained in 10,000 grains of potassic dichromate ( $K_2Cr_2O_7$ )?  $K = 39$ ;  $O = 16$ ;  $Cr = 52.5$ . How much oxygen is given off when the same quantity of the salt is heated with an excess of oil of vitriol? *June* 1865.

Potassic dichromate:—

$$K_2 = 2 \times 39 = 78$$

$$Cr_2 = 2 \times 52.5 = 105$$

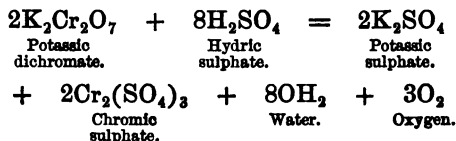
$$O_7 = 7 \times 16 = 112$$

295 = molecular weight.

In 295 parts of  $K_2Cr_2O_7$  there are 112 parts of O.  
 Therefore, in 10,000 parts of  $K_2Cr_2O_7$  there are  
 $\frac{112 \times 10000}{295} = 3796.61$  of oxygen.

Therefore the first answer is 3796.61 grains.

The equation representing the reaction is:—

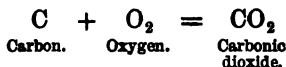


i.e. two molecules of potassic dichromate, containing 14 atoms of oxygen, yield 6 atoms of oxygen, which is three-sevenths of the contained oxygen—that is,  $\frac{3}{7} \times 3796.61 = 1627.12$  of oxygen.

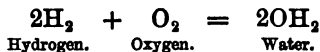
Therefore the second answer is 1627.12 grains.

**71. Name the substances which are formed when carbon, hydrogen, phosphorus, and sulphur respectively are burned in an excess of oxygen. June 1865—June 1867.**

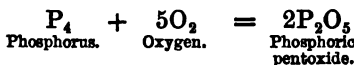
When carbon is burned in an excess of oxygen, carbonic dioxide is formed:—



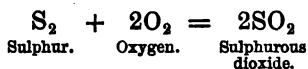
When hydrogen is burned in an excess of oxygen, water is formed:—



When phosphorus is burned in an excess of oxygen, phosphoric pentoxide is formed:—



When sulphur is burned in an excess of oxygen, sulphurous dioxide is formed :—



**72. A watch spring is burned in a closed vessel of oxygen.** State (a) whether the weight of the bottle and its contents is affected by the combustion; (b) what is the nature of the product formed by the combustion? (c) whether the grey metallic-looking globules, found at the bottom of the bottle after the experiment, consist of metallic iron; (d) whether the whole of the oxygen originally filling the bottle is still present, and, if so, in what form. *Jan. 1874.*

A steel watch spring, having a bit of lighted amadou fixed to its extremity, when introduced into a vessel of oxygen gas exhibits a most beautiful phenomenon of combustion. The oxygen here combines with the iron, and the heat evolved in combination is so great that the fused globules of black ferric oxide ( $\text{Fe}_3\text{O}_4$ ), after falling through half an inch of water, fix themselves in the plate in which the jar stands.

(a) The weight of the bottle and its contents is not affected by the combustion.

(b) Black oxide of iron ( $\text{Fe}_3\text{O}_4$ ), known as magnetic oxide of iron.

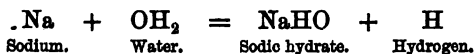
(c) No; they consist of oxide of iron ( $\text{Fe}_3\text{O}_4$ ).

(d) Yes, the oxygen is all present; but a part of it may be free, the remainder being combined with the iron.

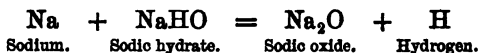
**73. Why do you consider two atoms of hydrogen to be equivalent to one atom of oxygen?** *Jan. 1872.*

Sodium, when acted upon by an excess of water, sets free some of the hydrogen of the water, and the

remainder of the constituents of the water goes to form sodic hydrate, thus :—



Now, by heating the sodic hydrate till it fuses, and adding an excess of sodium, the remainder of the hydrogen of the water is liberated and sodic oxide is formed, thus :—

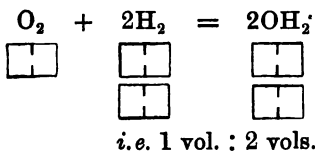


It is found by measurement that these two liberated quantities of hydrogen are equal; therefore in water there are two atoms of hydrogen, because no body has yet expelled it in more than two equal portions. The oxygen cannot be removed in parts, but all at once; we therefore say that *water contains one atom of oxygen to two atoms of hydrogen.*

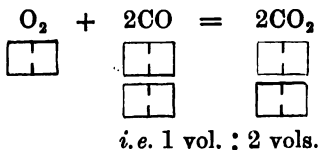
Now, hydrogen combines with chlorine atom with atom, since in their compound, hydric chloride, if the hydrogen or chlorine be replaced by another element, it is so replaced all at once and not by parts. This means that one atom of chlorine is equivalent to one atom of hydrogen. If in any compound chlorine replaces oxygen, two atoms of chlorine always replace one atom of oxygen; therefore *one atom of oxygen is equivalent to two atoms of chlorine, and therefore to two atoms of hydrogen.*

**74.** In what proportion by volume does oxygen combine with each of the following gases, viz. hydrogen, carbonic oxide, marsh gas, and olefant gas? *June 1865.*

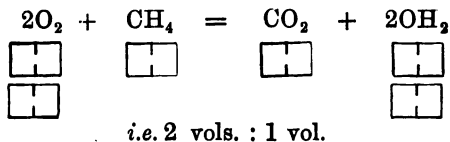
Combination with hydrogen :—



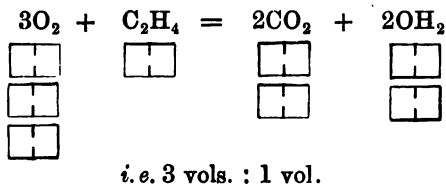
Combination with carbonic oxide :—



Combination with marsh gas :—



Combination with olefiant gas :—



**75.** Describe how you would prepare pure oxygen, and give an outline of the leading properties of this element. *Jan.* 1871.

The answer to the first part of this question will be found in No. 60, and that to the second part in No. 66.

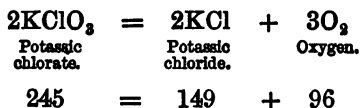
**76.** Oxygen is said to be a permanent gas and a great supporter of combustion. Illustrate each statement by a description of one or two experiments. *June 1872.*

The term permanent gas is *generally* used in contradistinction to a readily condensable vapour. That oxygen is a permanent gas—that is to say, impossible to be liquefied by any means at present at our disposal—has been proved to be false by a famous Swiss chemist.<sup>1</sup>

That oxygen is a supporter of combustion is easily proved from the following facts:—If a glowing wood splint be plunged into a vessel of oxygen, it at once bursts into flame; a candle and a fire burn in air by virtue of the oxygen which the air contains; if a candle be burned in a closed glass vessel, it will continue alight for a short time, and will then be extinguished, because all the oxygen has been used.

**77.** Describe the preparation of oxygen from potassic chloride. How many ounces of oxygen can be obtained from 115 ounces of potassic chlorate? *Jan. 1879.*

The first part of this question has been answered in No. 60. The equation representing the reaction is:—



<sup>1</sup> Quite recently oxygen, hydrogen, and nitrogen have all been reduced to the liquid state. Oxygen was first liquefied by Pictet at  $-140^\circ\text{C}$ . under a pressure of 320 atmospheres. Almost immediately afterwards Cailletet announced that he had succeeded in liquefying nitrogen and oxygen.

Thus we have :—

∴ 245 oz. of potassic chlorate yield 96 oz. of O  
 ∴ 1       ,,       ,,       yields  $\frac{96}{245}$        ,,  
 and 115   ,,       ,,       yield  $\frac{96 \times 115}{245}$  oz. of O  
                                   = 45.06 ounces of oxygen.

**78. Explain** by means of symbols the decomposition of mercuric oxide by heat. *June 1879.*

Mercuric oxide is decomposed by heat into its two elements, **mercury and oxygen**, according to this equation :—



**79. How would you distinguish oxygen from common air?** *June 1867.*

A taper with the wick red hot will burst into flame in oxygen, but not in air. **Nitric oxide forms with free oxygen brown fumes**, which are readily soluble in water. If, therefore, a few bubbles of that gas are passed into a jar containing air and placed over a pneumatic trough, brown fumes arise. These are at once dissolved in the water, which rises in the jar one-fifth of the height. If the jar contain pure oxygen, the water will rise nearly to the top.

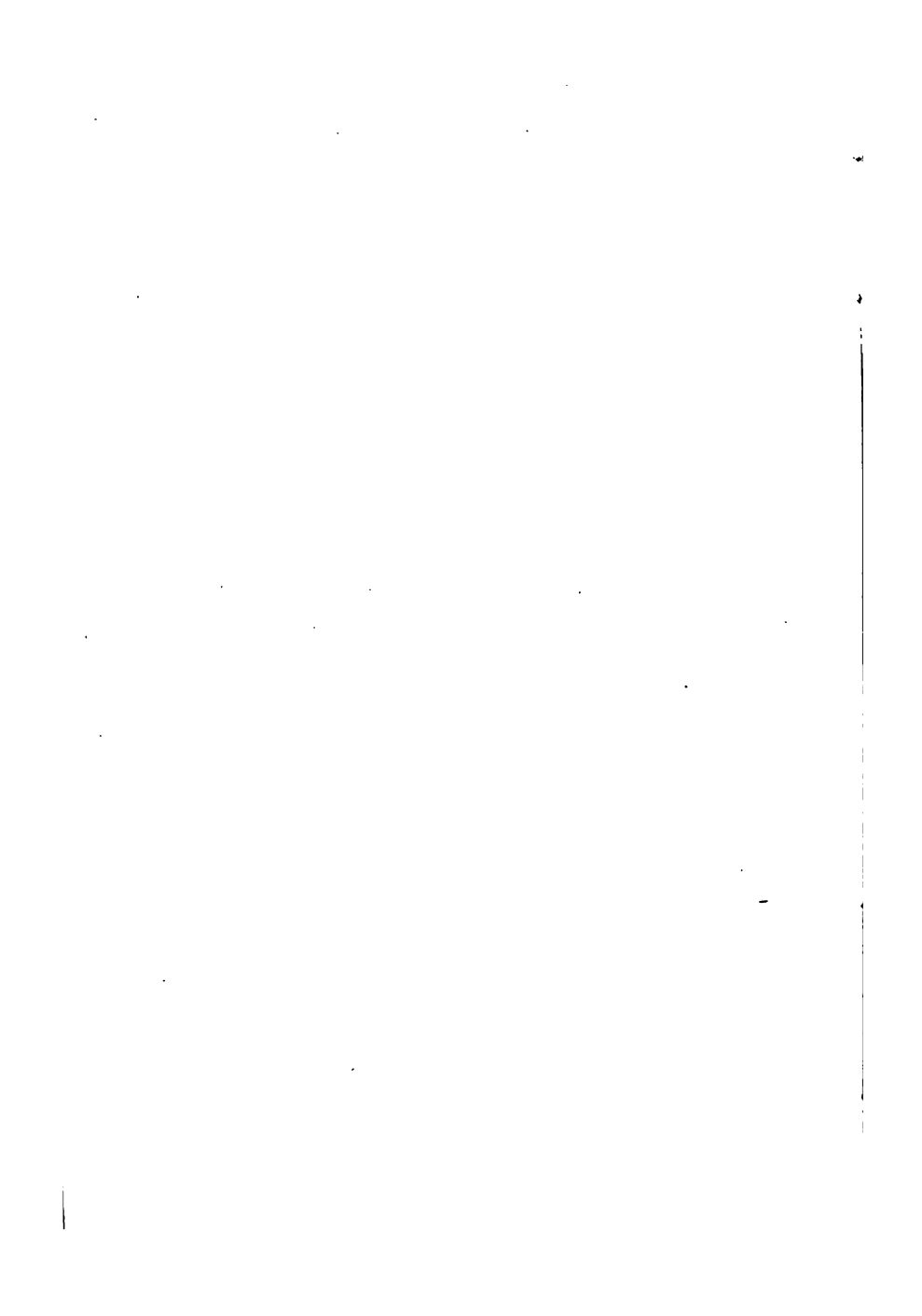
Instead of nitric oxide and water, a solution of **potassic pyrogallate** or a **stick of phosphorus** may be used in a similar manner.

**80. Name the substances which are formed when carbon, hydrogen, sulphur, and phosphorus are respectively burned in an excess of oxygen.**

Which of the following bodies can be burned in oxygen? Sulphur, nitrogen, coke, sulphurous acid, wax, iodine, chlorine, and ammonia. *June 1867.*

For the solution of the first part of the question see No. 71.

With regard to the second part, sulphur, coke, wax, and ammonia can be burned in oxygen; the others cannot.



## CHAPTER II.

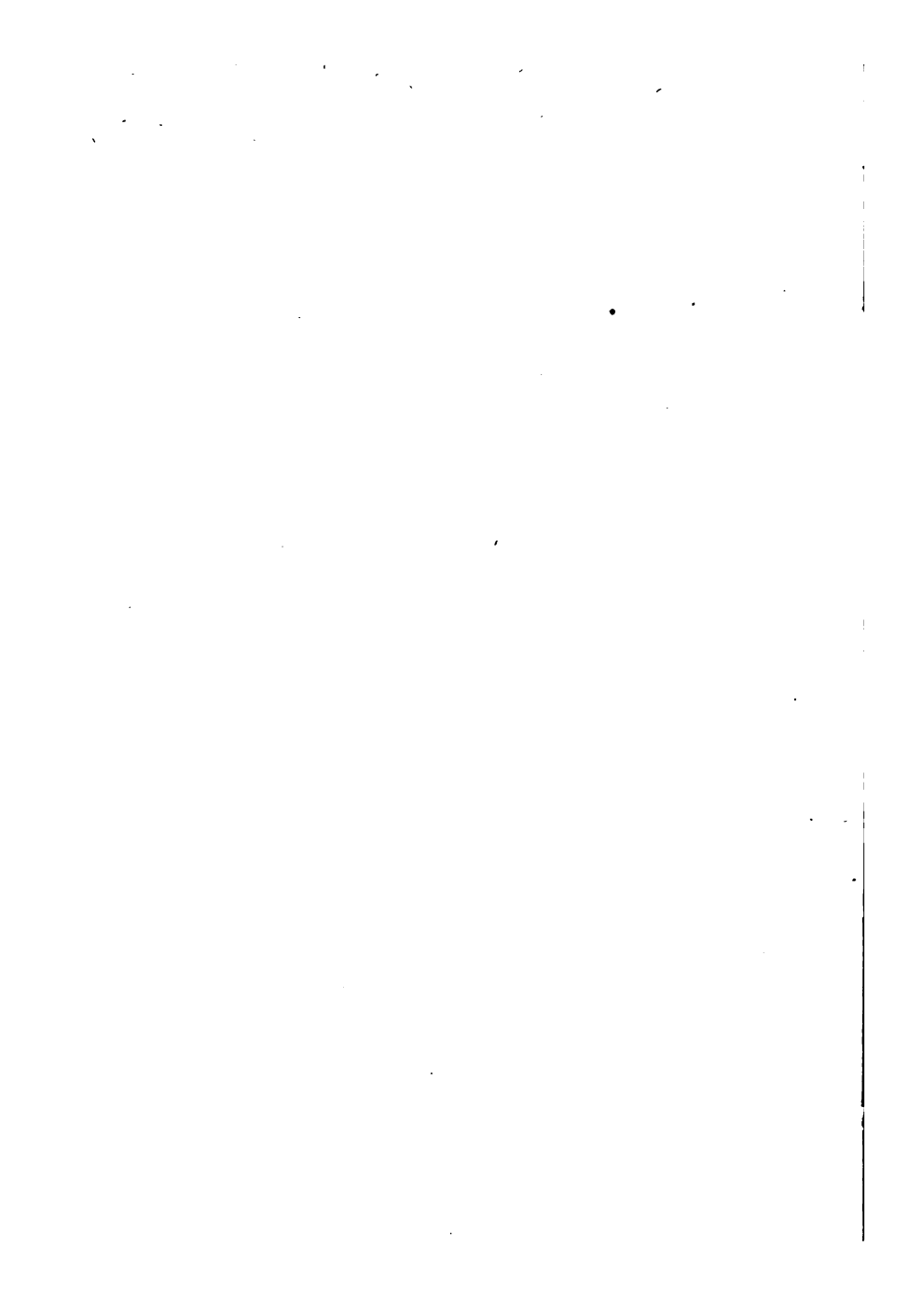
### HYDROGEN (H).

(Monad, as in HCl.)

$$\frac{(\text{H}_2) \text{ Molecular weight, } 1.}{\text{Molecular volume, } \boxed{11.2}} = 1 \text{ sp. gr.}$$

Or 1 gramme of H measures 11.2 litres.

1 grain of H measures 44.4 cubic inches.



## HYDROGEN.

**81.** What are the sources of hydrogen? *July 1857.*

Enumerate native compounds of the element hydrogen. *Jan. 1869.*

Hydrogen exists free in the gases given off from volcanoes. Some meteorites contain it free in their pores, and the spectrum analysis proves it to be present in the sun's atmosphere. It forms an ingredient of all animals and plants. It is found combined in marsh gas, which results from the decomposition of vegetable matter; in naphtha, petroleum, asphalte, and coal; in water, in ammonia and its salts, and in some other minerals. It is generally prepared from water or by the action of certain metals upon some acid containing hydrogen.

**82.** What are the predominating elementary constituents of plants and animals? *July 1856—July 1859.*

The predominating elementary constituents of plants and animals are:—

**Oxygen (O), Hydrogen (H), Nitrogen (N), Carbon (C).**

**83.** Water is said to be composed of equivalent quantities of its two constituents, or of two atoms of hydrogen and one atom of oxygen. Why do you con-

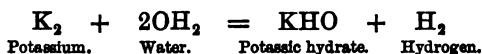
sider *two atoms of hydrogen* to be equivalent to *one atom of oxygen*? Jan. 1873.

This question has been answered under Oxygen, Ch. I., No. 73.

**84.** Describe how you would prepare hydrogen from water, and explain your process. June 1878.

I should prepare it in the following ways:—

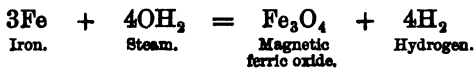
1st. By the action of **potassium** or some similar metal upon it.



This decomposition is so violent that the hydrogen **takes fire** if oxygen be present, and burns with a peculiar purple tint, owing to a certain amount of potassium being volatilised. The peculiar tint of the flame is characteristic of all potassium compounds.

The action is much the same if **sodium** be used instead of potassium. In this case, however, the hydrogen **does not take fire** unless the sodium be prevented from moving about, when its 'energy' is converted into heat.

2nd. By placing across a burning furnace a tube of iron or porcelain containing a quantity of **filings or turnings** of iron or some similar metal, and passing through it a stream of **vapour of water**. As this comes in contact with the heated iron, it yields its oxygen to the iron to form ferric oxide ( $\text{Fe}_2\text{O}_3$ ); whereupon the hydrogen is set free and may be collected over water.



3rd. By the action of white-hot platinum or similar metals a little water is decomposed into its elements.



4th. By the action of an electric current led into water by platinum electrodes it is decomposed as in No. 3.

**85.** What substance is formed when hydrogen is burnt in air or in oxygen? *Jan.* 1866.

How would you show that water is formed when hydrogen is permitted to burn in air? *Jan.* 1873.

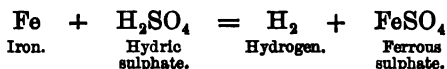
When hydrogen burns in air water is formed according to the equation:—



This is shown experimentally by lighting a jet of hydrogen which issues from an ordinary hydrogen bottle, and is thoroughly dried by making it pass through a U tube filled with fragments of calcic chloride ( $\text{CaCl}_2$ ) or pumice soaked in oil of vitriol ( $\text{H}_2\text{SO}_4$ ). The gas which is formed from the combustion is condensed by the cold walls of a glass receiver in which the hydrogen is made to burn, and drops of water may be collected. These drops I should prove to be water by testing them with blue and red litmus paper, upon which they would have no action, or by dropping upon them a small piece of potassium, which would at once burst into flame. Moreover, the liquid will be without taste.

**86.** What is the product of the action of diluted sulphuric acid upon iron? *July* 1853.

Iron is able to displace the hydrogen of the hydric sulphate ( $\text{H}_2\text{SO}_4$ ), according to this formula :—



The product of the reaction therefore is ferrous sulphate, or green vitriol, and free hydrogen. The hydrogen thus obtained is very impure, and has a most unpleasant smell, due to the presence in it of compounds of hydrogen with sulphur, carbon, &c., derived from the impure iron.

**87.** How would you prepare hydrogen gas? Give an explanation of your process. *July 1862—Jan. 1866—June 1866—June 1880.*

Describe how you would prepare hydrogen from water, zinc, and hydric sulphate; and explain your process by means of symbols. Sketch the leading properties of hydrogen. *Jan. 1870—June 1874—Jan. 1882.*

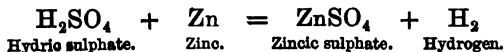
Describe by an equation what takes place when metallic zinc is acted upon by diluted hydrogen sulphate (sulphuric acid). *June 1869—June 1874.*

Give the preparation and properties of hydrogen gas. *July 1849—July 1855.*

The properties of hydrogen gas will be given in the next question.

The most ordinary way of preparing hydrogen gas is to extract it from the hydric sulphate ( $\text{H}_2\text{SO}_4$ ), from which the hydrogen is expelled by means of a metal such as zinc.

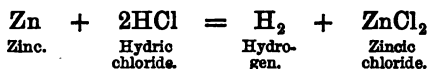
The reaction is expressed by :—



The hydric sulphate is always diluted, because concentrated hydric sulphate has no action upon zinc; if not sufficiently dilute, the zincic sulphate formed soon crystallises, and the action is stopped. If the action is proceeding, and then concentrated hydric sulphate be added, sulphurous dioxide is obtained, not hydrogen.

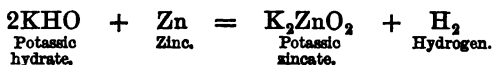
The hydrogen is set free, and there remains in the bottle a solution of zincic sulphate ( $\text{ZnSO}_4$ ), which by evaporation yields white crystals.

Another way of preparing this gas is to expel the *hydrogen* from hydric chloride ( $\text{HCl}$ ) by means of a metal, say zinc. The action which then takes place in the bottle may be represented by the following equation:—



Hydrogen is set free, and there remains a solution of zincic chloride ( $\text{ZnCl}_2$ ), which by evaporation yields a white deliquescent substance.

A *third way of preparing* hydrogen is by expelling the *hydrogen* from a caustic alkali, such as potassic hydrate ( $\text{KHO}$ ) or sodic hydrate ( $\text{NaHO}$ ). This process is distinguished from the two preceding ones in this, that the application of heat is required in order to expel the hydrogen from these compounds. The reaction is expressed by the following equation:—



Hydrogen is set free, and a solution of potassic zincate remains.

This process yields a very pure hydrogen, but somewhat slowly. By adding a quantity of iron filings to the zinc the action is very much accelerated, although

the iron undergoes no change. This *action of presence* is similar to that of a plate of copper, which increases the rapidity with which a sheet of zinc dissolves in hydric chloride (HCl).

**88.** Give the preparation and properties of hydrogen gas. *July 1849—July 1855.*

Describe the characters of hydrogen gas, and the processes for preparing it. *July 1857.*

The various preparations have been given in the preceding number.

Hydrogen is a colourless invisible gas; that is to say, transparent like air. When pure it has neither taste nor smell. It is the lightest body known, being more than fourteen times lighter than air; its density is .0693. Hydrogen diffuses most rapidly into other gases, so much so as to render it unfit for filling balloons for any considerable time. When a light is applied hydrogen burns in air with a flame that is very slightly luminous but extremely hot. Yet it will not support the combustion of a candle nor the life of an animal. Hydrogen is but slightly soluble in water.

**89.** How would you prove that hydrogen is lighter than air? *Jan. 1866.*

Hydrogen is about fourteen times lighter than air. That such is the case I would show by putting forward the following reasons:—

(1) It may be collected by upward displacement.

(2) A small balloon or soap bubble filled with hydrogen rises in the air, in spite of the weight of the material of the balloon.

(3) If a glass bell-jar be hung from one arm of a balance, and weights be placed in the pan of the other

arm until it is horizontal, then if hydrogen be allowed to pass into the jar in place of the air, the jar immediately begins to rise, as its weight is now less than that of the weights.

**90.** How is hydrogen gas distinguished from nitrogen? how from oxygen? and how from carbonic acid? *July 1862—Jan. 1866.*

*Hydrogen is distinguished from nitrogen by the fact that hydrogen burns with a light flame when in contact with air, whereas nitrogen does not.*

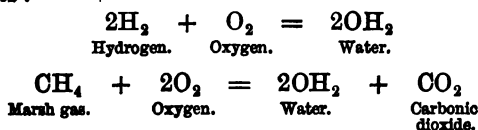
*Hydrogen is distinguished from oxygen by the same fact as that which distinguishes it from nitrogen. Moreover the taper which lights the hydrogen will be put out, whilst if the wick be still incandescent it will be re-ignited, and will burn with great brilliancy when lowered into a vessel containing oxygen.*

*Hydrogen is distinguished from carbonic acid ( $\text{CO}_2$ ) in that the latter neither burns nor supports combustion. Moreover lime-water ( $\text{CaH}_2\text{O}_2$ ) if poured into the vessel containing hydrogen will remain unchanged, whilst if poured into the vessel containing carbonic acid it will at once become milky. Again, if both vessels be left open for a short time, the hydrogen will have completely disappeared, whereas the carbonic acid will remain in the vessel for some time. That such is the case may be easily proved by the fact that a lighted taper plunged into the hydrogen jar will neither cause the gas to burn nor be itself extinguished, whereas when lowered into the carbonic acid vessel it will be at once extinguished.*

**91.** Two bottles, one filled with hydrogen and the other with marsh gas, are given to you with the request to ascertain which of the two contains hydrogen. Ex-

plain how you would solve the problem. *June 1878—June 1880.*

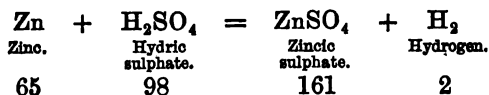
I should first pour a little lime-water into each jar ; it would remain clear. Then I should apply a flame. Both the hydrogen and the marsh gas would be enkindled and burn with a pale flame, with the following results :—



The lime-water in the jar containing hydrogen would remain clear, as the result of the combustion would be merely water. But the lime-water in the jar containing marsh gas would become cloudy almost immediately, because the result of the combustion would be carbonic dioxide, which forms with lime an insoluble calcic carbonate ( $\text{CaCO}_3$ ).

92. Taking the atomic weight of zinc as 65, what weight of hydrogen would be evolved according to this process (viz. by sulphuric acid) by the solution of 1 kilogramme of zinc ? *June 1869.*

The reaction is represented by the equation :—



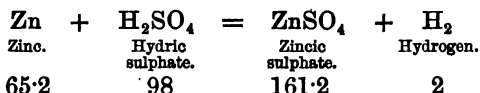
Thus 65 grammes of Zn evolve 2 grs. of H

$$\begin{array}{ccccccc}
 \therefore & 1 & & " & & " & \frac{2}{65} & " \\
 \therefore & 1000 & & " & & " & \frac{2 \times 1000}{65} & 
 \end{array}$$

=30.769 grammes of hydrogen.

**93.** How much hydrogen could you obtain by the solution of 100 grammes of zinc? (Atomic weight of zinc=65·2.) *June 1874.*

The reaction is shown by the following equation :—



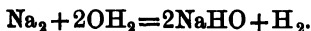
According to the preceding question the answer is obtained thus :—

65·2 grammes of zinc cause 2 grs. of H to evolve

$$\therefore \begin{array}{ccccccc} 1 & & " & & " & & \frac{2}{65\cdot2} & & " & & " \\ & & & & & & \frac{2 \times 100}{65\cdot2} & = & 3\cdot067 & \text{grammes} \end{array}$$

or  $3\cdot067 \times 11\cdot2 \text{ litres} = 34\cdot350 \text{ litres of hydrogen.}$

**94.** The action of sodium on water is expressed by the equation :—



How much water is required to take part in this reaction in order to obtain 22·38 litres of hydrogen at 0° C. and 760 mm. pressure? *June 1875.*

22·38 litres of hydrogen weigh 2 grammes ; therefore, from the mere inspection of the equation, 2 molecules of water are needed in order to yield one molecule of hydrogen ; or, **36 grammes of water are needed** in order to yield 2 grammes or 22·38 litres of hydrogen (H). And 36 grammes of water occupy a volume represented by ·036 litre.

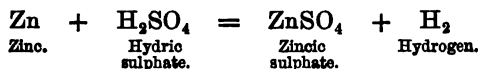
**95.** The weight of 11·2 litres of hydrogen under normal conditions being 1 gramme, what are the weights of 100 litres of oxygen, carbonic oxide, car-

bonic acid, chlorine, and ammonia gases respectively, under the same conditions? *June 1870.*

11.2 litres of hydrogen (H) weigh 1 gramme  
 $\therefore 100 \quad ,, \quad ,, \quad \text{will weigh } 8.927 \text{ grammes}$   
 $\therefore 100 \quad ,, \quad \text{oxygen (O) will weigh } 8.927 \times 16 = 142.832 \text{ grammes}$   
 $\therefore 100 \quad ,, \quad \text{carbonic oxide (CO) will weigh } 8.927 \times \frac{28}{2} = 124.978 \text{ grammes}$   
 $\therefore 100 \quad ,, \quad \text{carbonic acid (CO}_2\text{) will weigh } 8.927 \times \frac{44}{2} = 196.394 \text{ grammes}$   
 $\therefore 100 \quad ,, \quad \text{chlorine (Cl) will weigh } 8.927 \times 35.5 = 316.908 \text{ grammes}$   
 $\therefore 100 \quad ,, \quad \text{ammonia (H}_3\text{N) will weigh } 8.927 \times \frac{17}{2} = 75.879 \text{ grammes.}$

**96. What are the products of the solution of zinc in dilute sulphuric acid? How is the appearance of the solution altered by bringing copper or platinum into contact with the zinc? *July 1847—July 1853.***

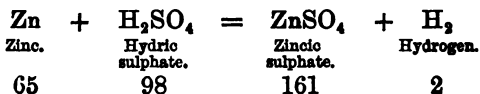
The products are **free hydrogen** and a solution of **zincic sulphate**, according to the equation:—



If a plate of platinum or copper be simply introduced into the liquid no change is produced; but if the platinum or copper touch the zinc, either within or without the liquid, a voltaic couple is formed, the hydrogen is given off with greater rapidity from the surface of the platinum or copper, not from that of the zinc,

**97.** What weight of oil of vitriol ( $\text{H}_2\text{SO}_4$ ) must be decomposed for the evolution of 1 gramme of hydrogen? *June 1867.*

The equation according to this reaction is :—



$\therefore$  1 gramme of hydrogen is produced by the decomposition of  $\frac{98}{2} = 49$  grammes of hydric sulphate.

**98.** How much zinc would be required for the evolution of 1,000 c.c. of hydrogen at normal temperature and pressure, the atomic weight of Zn, O, and S being respectively 65, 16, and 32? *Jan. 1882.*

As 1000 c.c. of hydrogen is the same as 1 litre, and 11.2 litres weigh one gramme,

$$1 \text{ litre will weigh } \frac{1}{11.2} = .089 \text{ gramme.}$$

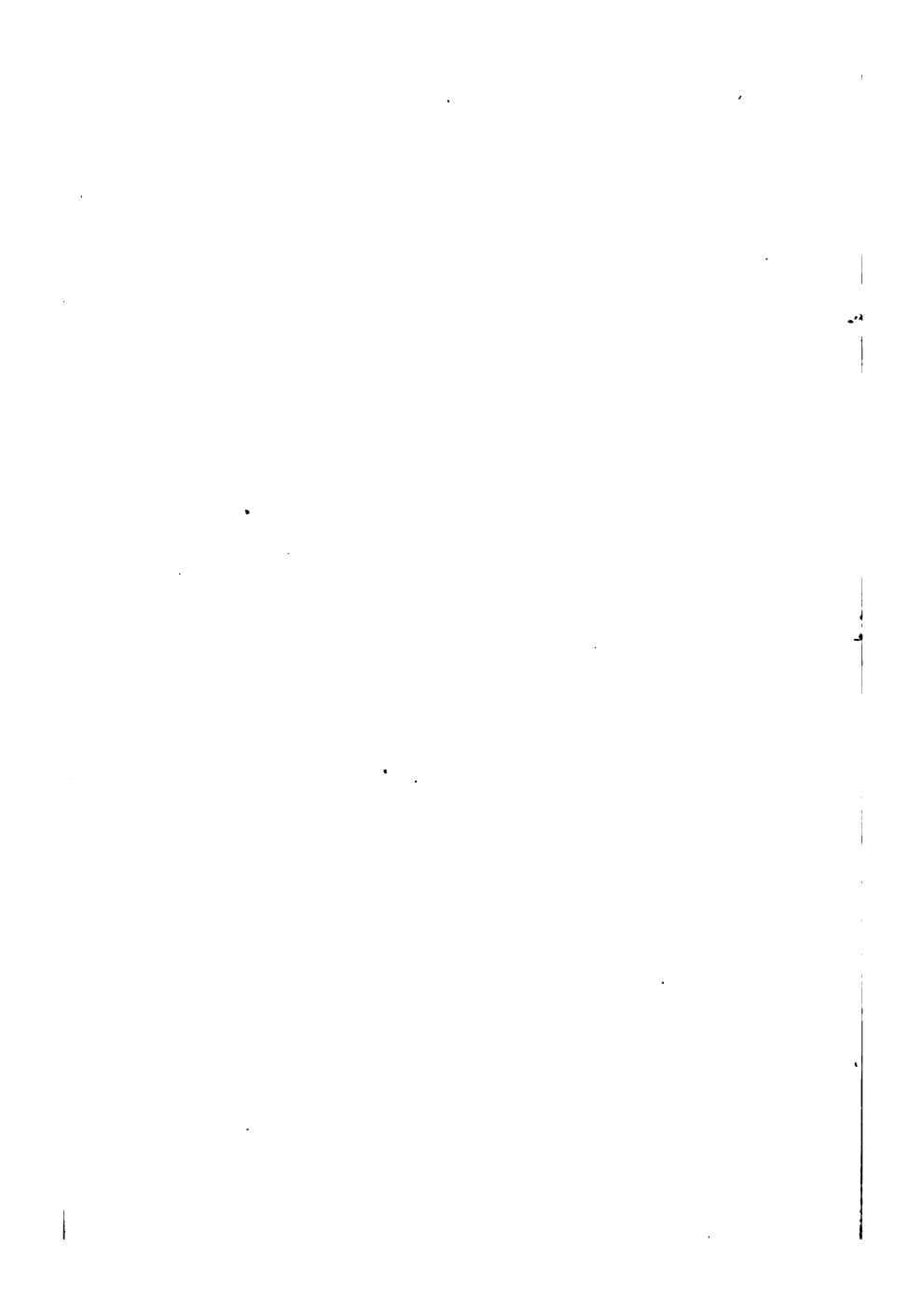
Now from the equation given in the preceding number we gather that

2 grammes of H require 65 grammes of Zn

65	
$\frac{2}{2}$	" "

$.089$	"	$\frac{65 \times .089}{2} = 2.892$	grammes
--------	---	------------------------------------	---------

of zinc.



## CHAPTER III.

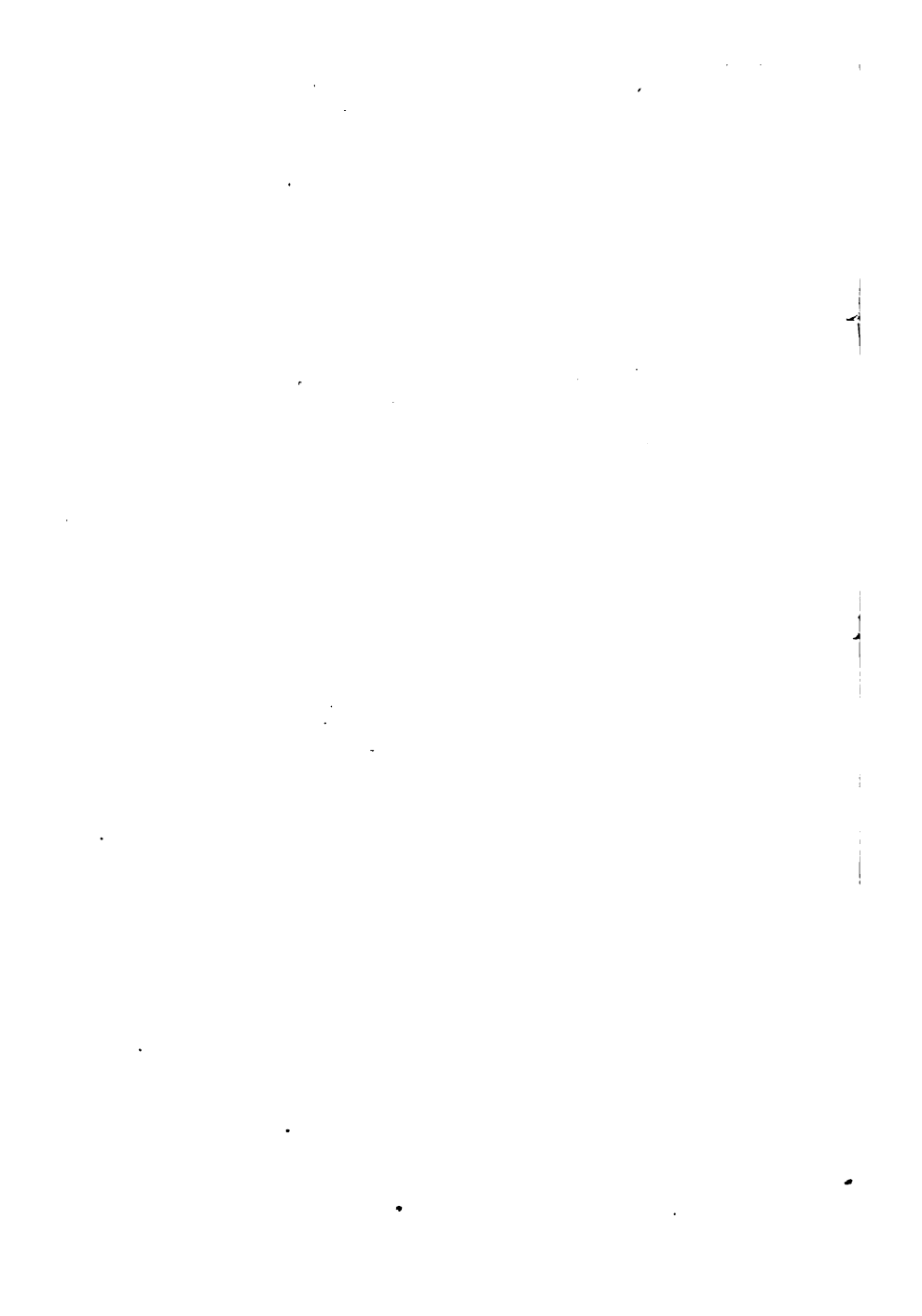
### WATER ( $\text{OH}_2$ ).

(Hydric Oxide.)

$$\frac{\text{Molecular weight, 18.}}{\text{Molecular volume, } \boxed{\phantom{00}}} = 9 \text{ sp. gr.}$$

Or 9 grammes of Steam measure 11.2 litres.

9 grains of Steam measure 44.4 cubic inches.



## WATER.

**99.** Describe an arrangement for decomposing water by the galvanic current. *Jan. 1864—June 1866.*

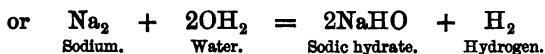
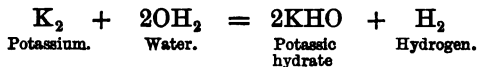
Water is said to be a compound of hydrogen and oxygen. Describe experiments in proof of this view. *July 1858—Jan. 1871.*

How would you extract oxygen from water? *Jan. 1873.*

Water may be decomposed and its elements demonstrated by the action of a strong battery. The wire in contact with the zinc of the battery is passed, water-tight, through a bent tube, as is also the wire that is in contact with the acid. Each wire has a slip of platinum foil (Pt) attached to the end that dips in the water of the bent tube. The electric current decomposes the water; the hydrogen, being electro-positive, collects in the arm of the tube into which dips the wire attached to the zinc; and the oxygen, being electro-negative, collects in the other arm of the tube, in which dips the wire in contact with the acid. In order to render the water a better conductor of the electric current, it is slightly acidulated with hydric sulphate.

**100.** How would you prepare hydrogen from water without the assistance of an acid? And explain your process. *June 1866.*

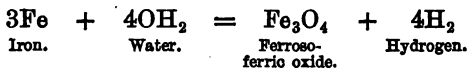
I should decompose the water by potassium or by sodium. When placed in contact with the water, both these metals violently react on it, forming hydrates, viz. potassic hydrate (KHO) or sodic hydrate (NaHO) respectively, at the same time setting half the hydrogen of the water free :—



The best way of performing this experiment without any explosion is to sink potassium or sodium in the water through a lead tube. As long as these metals are below the level of the water, there is no fear of explosion. I could also obtain hydrogen from water without the assistance of an acid, by passing through it a current of electricity (see No. 99), or by passing steam over red-hot iron. These act much the same as sodium and potassium do, only that the action is not so violent, while, moreover, the hydrogen of the water is set free.

**101.** Explain the decomposition of steam by red-hot iron. *June 1865.*

If steam is made to pass over hot iron, the steam is decomposed. The iron is oxidised, forming ferric oxide, and the hydrogen is set free. The reaction may be represented by :—



The current of steam must be rapid, in order to carry off the hydrogen as fast as it is produced ; otherwise it would reduce the ferric oxide to the metallic state and itself be reconverted into water.

**102.** How can a mixture of two volumes of hydrogen and one volume of oxygen be converted into water? *Jan. 1867.*

By means of a eudiometer, which is a graduated tube, at the top of which are sealed two platinum wires. The mixed gases are placed in this eudiometer, and an electric spark, from a coil or any other electric machine, is passed between. The spark causes these two gases to combine, forming water.

They may also be combined by the application of a lighted taper, or when brought under the influence of spongy platinum.

**103.** Describe properties of oxygen, hydrogen, and water, which justify the conclusion that water is not an elementary substance. *June 1864.*

When an electric current is passed by platinum terminals through pure water, and into glass tubes also filled with water and inverted over the terminals, it is found that the tubes are gradually filled with gas, one tube containing twice as much gas as the other. If to the tube containing the greater quantity of gas a little lime-water be added, and then a match applied to the gas, the latter burns with a pale flame, and the lime-water is not rendered turbid; this proves it to be *hydrogen*. If to the tube containing the lesser quantity of gas a little nitric oxide be added, brown fumes are produced, proving it to be *oxygen*. These two gases do not proceed from the platinum, for that is an element, but from the water, which is therefore a compound.

**104.** A mixture of 10 cubic centimetres of oxygen and 20 cubic centimetres of hydrogen, kept at the temperature of 120° C. in a eudiometer over mercury, is

exposed to the action of an electric spark. **How is the gaseous mixture affected by the experiment?** *Jan. 1874.*

The two gases combine wholly to form water, and no free oxygen or hydrogen is left, because  $10 : 20 :: 1 : 2$ , which is exactly the proportion in which these two gases combine by volume. But as the molecular volume of all gases, with few exceptions, is 2, *i.e.* the same as that of two atoms of hydrogen, and water at the temperature of  $120^{\circ}\text{C}$ . being a gas, the volume of the steam produced is that of the hydrogen in it—that is, 20 cubic centimetres.

**105.** 50 cubic centimetres of oxygen and 150 cubic centimetres of hydrogen are placed in a dry eudiometer at a temperature of  $120^{\circ}\text{C}$ ., and under the normal atmospheric pressure; an electric spark is then passed through the mixture. **What will be the volume after the explosion, the temperature and pressure being supposed to remain as they were?** *Jan. 1876.*

50 c.c. of oxygen will combine with 100 c.c. of hydrogen, forming 100 c.c. of vapour of water. In the vessel there will remain 50 c.c. of free hydrogen and 100 c.c. of steam.

**106.** What are the constituents of water? *July 1860.*

The constituents of pure water are hydrogen and oxygen combined in the proportion of 2 volumes of H for 1 volume of O.

**107.** How may the constituents of water be obtained?

The answer to this question, implying the manner of

preparing hydrogen and oxygen, will be found solved by No. 60 and No. 87.

**108.** Give the composition of water by weight and by volume. *July 1858—Jan. 1862.*

State the proportions by volume and by weight in which the constituent elements of water are given off. *Jan. 1864—June 1866.*

The composition of water is :—

By weight 2 of H to 16 of O or 11.11 of H and 88.88 of O per %.

By volume 2 of H to 1 of O.

**109.** Describe the method you would use to determine the composition of water (1) by volume, (2) by weight. *Jan. 1878.*

There are two ways of solving this question—by analysis or by synthesis. We shall here take the first.

To determine by analysis the composition of water by volume, introduce into a bent tube, of which both arms are in contact with the wires of a galvanic battery, some water previously acidulated with hydric sulphate, in order to make the water a better conductor of electricity. After a short time bubbles of gas begin to rise in both arms of the tube, but in one more rapidly than in the other; in fact, it will be found that the gas in one arm of the tube is in volume exactly double that in the other. The latter is easily ascertained to be hydrogen, whilst the other tube contains oxygen. Thus water is composed by volume of 2 of hydrogen and 1 of oxygen. Hence its formula is  $\text{OH}_2$ .

Now the sp. g. of oxygen is 16. In other words, a given volume of oxygen is 16 times as heavy as the same volume of hydrogen, i. e. 1 volume of oxygen is 8 times

as heavy as 2 volumes of hydrogen ; therefore the composition of water by weight is 8 of oxygen to 1 of hydrogen, or 16 of oxygen to 2 of hydrogen.

**110.** Give the character of water in a pure state.  
*July 1858.*

Water, if pure, has no smell. If viewed in small quantities it is colourless ; but seen through a tube of 6 feet it has a pale blue tint, which passes to a deep bluish green as the tube increases in length. It dissolves a great number of substances without altering their properties, from which it may easily be driven off by heat. For these reasons it is used by chemists as a solvent. It forms a necessary ingredient, under the name of **water of crystallisation**, in the formation of some crystals. It assumes in nature the **three forms** of bodies, solid (ice or snow), liquid (water), and gas (steam). Water is decomposed into its elements (H and O) by heat. It has no action upon litmus paper.

**111.** During the Abyssinian expedition drinkable water had to be prepared from sea water. Show how this can be done. *June 1868.*

How can pure water be prepared from sea water?  
*Jan. 1863—Jan. 1882.*

Pure water is obtained from sea water by the process of distillation. This is effected in large copper or iron boilers, provided with a long neck of tin-lined tubing, coiled into spirals and immersed in cold water that is frequently renewed. The water thus procured is called **distilled water**, and serves for laboratory purposes. The ships of the Royal Navy, and nearly all sea-going steamers, are fitted with suitable distillatory apparatus.

As organic matter is often present in sea water, the distillate is liable to acquire a disagreeable taste, in consequence of a portion of the impurities undergoing decomposition during distillation. This, however, is entirely got rid of by filtration through charcoal, after due aëration, which renders the water agreeable and wholesome as a beverage.

**112.** What are the tests of the purity of water?  
*Jan. 1863.*

The tests of its purity are if, when separate portions are mixed with a few drops of solution of baric chloride ( $\text{BaCl}_2$ ), or argentic nitrate ( $\text{AgNO}_3$ ), or ammoniac oxalate, it does not give any precipitate. Or better, place a few drops on clean platinum foil, and warm gently. The water should wholly evaporate and leave the foil without a stain.

**113.** Enumerate the most common constituents of spring water. *Jan. 1867.*

Mention the most common impurities in spring water. *July 1860.*

**Gases:** Carbonic dioxide ( $\text{CO}_2$ ); hydric sulphide ( $\text{H}_2\text{S}$ ).

**Solids:** Calcic carbonate ( $\text{CaCO}_3$ ); calcic sulphate ( $\text{CaSO}_4$ ); sodic chloride ( $\text{NaCl}$ ); ~~manganic~~ <sup>*Magnesium*</sup> sulphate ( $\text{MgSO}_4$ ).

**Ammoniac salts:** Nitrates and nitrites derived from decomposition of sewage.

**Organic matter.**

**114.** Enumerate the principal constituents of sea water. *Jan. 1863—June 1868—Jan. 1882.*

The principal constituents of sea water are:—

Sodic and potassic chloride ( $\text{NaCl}$ ,  $\text{KCl}$ ); magnesian

ohloride ( $\text{MgCl}_2$ ), bromide ( $\text{MgBr}_2$ ), and sulphate ( $\text{MgSO}_4$ ); calcic sulphate ( $\text{CaSO}_4$ ) and carbonate ( $\text{CaCO}_3$ ).

**115.** In what respects does rain water differ from sea water? *Jan. 1869.*

Rain water differs from sea water chiefly in that it contains no solids dissolved in it, whereas sea water has in solution sodic chloride ( $\text{NaCl}$ ), bromides, iodides, and magnesian chloride ( $\text{MgCl}_2$ ), calcic carbonate ( $\text{CaCO}_3$ ) and sulphate ( $\text{CaSO}_4$ ), which are usually found in sea water. Also rain water on that account differs from sea water in density, this last being much more dense on account of the various salts dissolved in it.

**116.** Give the earthy impurities which are the frequent causes of its hardness and of deposits in boilers, and how they are removed.<sup>1</sup> *July 1846—July 1858—Jan. 1870.*

What is meant by the term 'hardness' as applied to water? *Jan. 1870.*

By the term hardness, as applied to water, is meant that the water holds in solution calcic carbonate and calcic and magnesian sulphate, which decompose ordinary soap, and, by forming an insoluble soap which grates on the hand, deprives it of its cleansing properties. The soap is then said to 'curdle.' The calcic carbonate ( $\text{CaCO}_3$ ) is removed by the boiling of the

<sup>1</sup> Some authors distinguish between *temporary* hardness and *permanent* hardness. The first is due to the presence of soluble calcic carbonate, which may be removed by adding lime to it, or by boiling. The second is due to the presence of magnesian or calcic sulphate, which cannot be removed by boiling.

water, or by mixing it with lime; the calcic and magnesian sulphates ( $\text{CaSO}_4, \text{MgSO}_4$ ) by the addition of sodic carbonate ( $\text{Na}_2\text{CO}_3$ ). This fact is practically well known to laundresses, by whom sodic carbonate goes under the name of washing soda.

**117.** How would you ascertain whether a particular sample of water is hard or not? *Jan. 1870.*

As ordinary soap is very impure, I would test the water with a solution of a pure soap in alcohol, by adding a little to the water contained in a bottle, which is then briskly shaken. If a curd is formed, I should say the water was hard; but if no curd is formed, but a froth is produced with a small quantity of soap solution, I should say it was soft. This mode of testing the hardness of water is known under the name of 'Clarke's soap test.'

**118.** Three samples of water are given you; one is a hard water, another a soft water, and the third is sea water. What chemical experiments would enable you to discriminate between them? *June 1877.*

To a portion of each sample contained in similar bottles add a few drops of a solution of soap in alcohol and shake; a persistent froth is produced in the soft water, while curds are produced in the other two. To a small fresh portion of these two samples add a solution of argentic nitrate: a very dense white precipitate is produced in the sea water, whilst a slight precipitate, or only a cloudiness, is produced in the hard water.

**119.** You boil common well water for a few minutes, and observe the separation of a white precipitate. How do you explain the formation of the pre-

precipitate? How would you test your explanation by experiment? *Jan. 1875.*

Well water contains calcic carbonate in solution, which salt is not soluble in pure water, but is held in solution by carbonic dioxide, a gas also present in well water. Cold water dissolves more gas than hot water, and boiling water dissolves practically none. Therefore, on boiling the water, the gas, carbonic dioxide, escapes and the calcic carbonate is rendered insoluble and falls as a white precipitate.

I should prove that carbonic dioxide escaped from the water on boiling—by boiling it in a flask fitted with a cork and bent tube dipping into lime-water, so that the steam and gases escaping through the tube should pass through the lime-water: this would render the lime-water turbid, which is only done by carbonic dioxide.

I should prove that the gas carbonic dioxide holds the calcic carbonate in solution, by passing this gas through the boiled well water when cold, and I should find that the precipitate would gradually disappear.

**120.** Give the composition of river water; and point out the difference which exists between the constituents of rivers and wells, with the cause of the greater impurity of the one compared with the other. *Jan. 1860.*

River water consists of spring water plus that derived from the surface-draining of the land. Thus river water contains all the impurities of spring water, such as calcic carbonate ( $\text{CaCO}_3$ ) and calcic sulphate ( $\text{CaSO}_4$ ), and, moreover, impurities derived from the decay of organic matter, animal or vegetable.

However, running or river water is endued with

a partial **self-purifying power**. The continual exposure of fresh surfaces to the action of the atmosphere promotes the oxidation of the organic matter. And again, the same exposure of fresh surfaces to the atmosphere causes the water to **give up some of the carbonic dioxide** it holds in solution, thereby causing the deposition of calcic carbonate as a sediment.

The water of the wells, on the contrary, having percolated through various layers of salts, becomes **saturated with them**; and, as it is scarcely in contact with the air, it keeps all these salts in solution. Thus it is that well water is generally less pure than river water.

**121.** The spring water of our chalk districts is much harder than the river water of the same localities. Why is this the case? *June 1880.*

Because river water receives its **main supply from the rainfall**. Now, the greater part of this water does not come into contact with any chalk, and is, therefore, not hard, but flows off directly from the fields and meadows into the brooks, and from the brooks into the rivers. On the contrary, the *whole* mass of spring water having **percolated through various layers of calcic salts** is, so to speak, saturated with calcic carbonate. Thus it is that the spring water of our chalk districts is much harder than that of the river water of the same locality. Also rivers gradually **give off carbonic dioxide** (with other gases) to the air as they flow on, and consequently some calcic carbonate may be deposited.

**122.** The hard water of our chalk districts is rendered soft by addition of lime-water. Explain fully

why lime-water is able to produce this result. *June 1871.*

The well water at Canterbury is rendered soft by addition of an aqueous solution of lime. Explain why lime is able to render some kinds of hard water soft. *June 1873—June 1880.*

The calcic carbonate, which makes these waters hard, is held in solution through the presence in the water of a certain amount of free carbonic dioxide ( $\text{CO}_2$ ). Now, by adding calcic oxide or lime ( $\text{CaO}$ ) to this water, the lime combines with the carbonic dioxide, forming calcic carbonate ( $\text{CaCO}_3$ ). This calcic carbonate, and also that previously held in solution, are both precipitated, thus rendering the water soft. Now, this addition of lime would be of no effect on 'permanent' hard water—namely, that which is due to the presence of calcic and magnesian sulphate. For these sulphates are held in solution by the water, entirely independently of the presence of carbonic dioxide. Lime added to such water would make the water harder than it was.

This process is called 'Clarke's process.'

**123.** Which are the gases generally held in solution by water? *July 1848.*

The gases generally held in solution by water are oxygen, nitrogen, and carbonic dioxide.

**124.** Give the peculiar constituents of aerated, saline, chalybeate, and sulphurous mineral waters. *July 1848.*

Water is said to be aerated when containing much air in solution; saline when containing sodic chloride, sodic carbonate, and other salts; chalybeate when con-

taining iron (Fe); **sulphurous mineral water** when containing sulphuretted hydrogen. This last is also called **hepatic water**.

**125.** At what temperature is water at its point of greatest density? *June 1866.*

**4° C.** is the temperature at which water is heavier than at any other temperature, and this is hence called its point of **maximum density**.

**126.** What effect would continuous frosty weather have on our lakes and rivers if water expanded and contracted according to the same rule as a piece of solid iron? *June 1866.*

Water is one of those substances which by assuming the solid form becomes less dense. If it were unfortunately otherwise, as soon as a layer of ice was formed on the surface of a lake or river, its weight would drag it to the bottom; and so again and again. The consequence would be that after a few nights' frost the whole bed of the river would be one mass of ice, which the heat of the summer sun would be quite unable to melt.

**127.** A specimen of spring water is supposed to contain **sulphuretted hydrogen** (hydric sulphide). How would you ascertain whether any sulphuretted hydrogen is present? *Jan. 1871.*

By adding to the suspected liquid a few drops of **plumbic acetate** (sugar of lead). At once a black precipitate of **plumbic sulphide** ( $\text{PbS}$ ) is formed.

**128.** Explain the decomposition of water by potassium in presence and absence of atmospheric air. *Jan. 1865.*

On dropping potassium on water, owing to its great

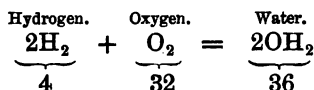
attraction for oxygen, it decomposes the water, setting free half its hydrogen and combining with the other half and with the oxygen. In the reaction great heat is given out, quite sufficient to raise the hydrogen to the ignition point; therefore, if air or oxygen be present, the hydrogen will burn, and a portion of the potassium will be volatilised and will colour the flame violet. Of course, if air or oxygen be absent, the free hydrogen will not burn, but will remain free.

**129.** What takes place in the slaking of quicklime with water, and in the setting of plaster of Paris? *July 1853.*

In the slaking of quicklime, the lime or calcic oxide forms with water a compound called a hydrate ( $\text{CaH}_2\text{O}_2$ ). This combination is accompanied with great emission of heat. The lime first swells up, then cracks, and is completely reduced to a fine powder. The same happens with plaster of Paris (calcic sulphate,  $\text{CaSO}_4$ ), which is nothing else but calcined gypsum—that is to say, gypsum from which nearly all the water has been driven by exposure to the heat of  $127^\circ\text{C}$ . Now, when mixed with water, so as to form a paste, heat of combination is evolved, and the hydrate or gypsum is again formed, so that the plaster of Paris becomes hard, or, in other words, *sets*.

**130.** Some oxide of copper in a glass tube loses 16 grains' weight when heated in a current of hydrogen. What quantity of water should be formed? *July 1863.*

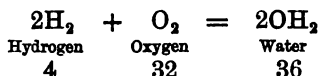
The following equation represents the reaction:—



From 32 grains of oxygen 36 grains of water are formed ; therefore from 16 grains of oxygen 18 grains of water will be formed.

**131. How many grammes of oxygen and how many grammes of hydrogen are required in order to prepare 500 gr. of water ? How many litres will the hydrogen measure if each gramme measure 11·2 litres ? How many litres will the oxygen measure, its density being 16 times as great as that of hydrogen ? Jan. 1866.**

The equation of the reaction is:—



36 grammes of water are required to prepare 4 gr. of H

$$\begin{array}{rcccc} 1 & " & " & " & \frac{4}{36} \\ 500 & " & " & " & \frac{4 \times 500}{36} \end{array}$$

= 55·56 gr. of hydrogen.

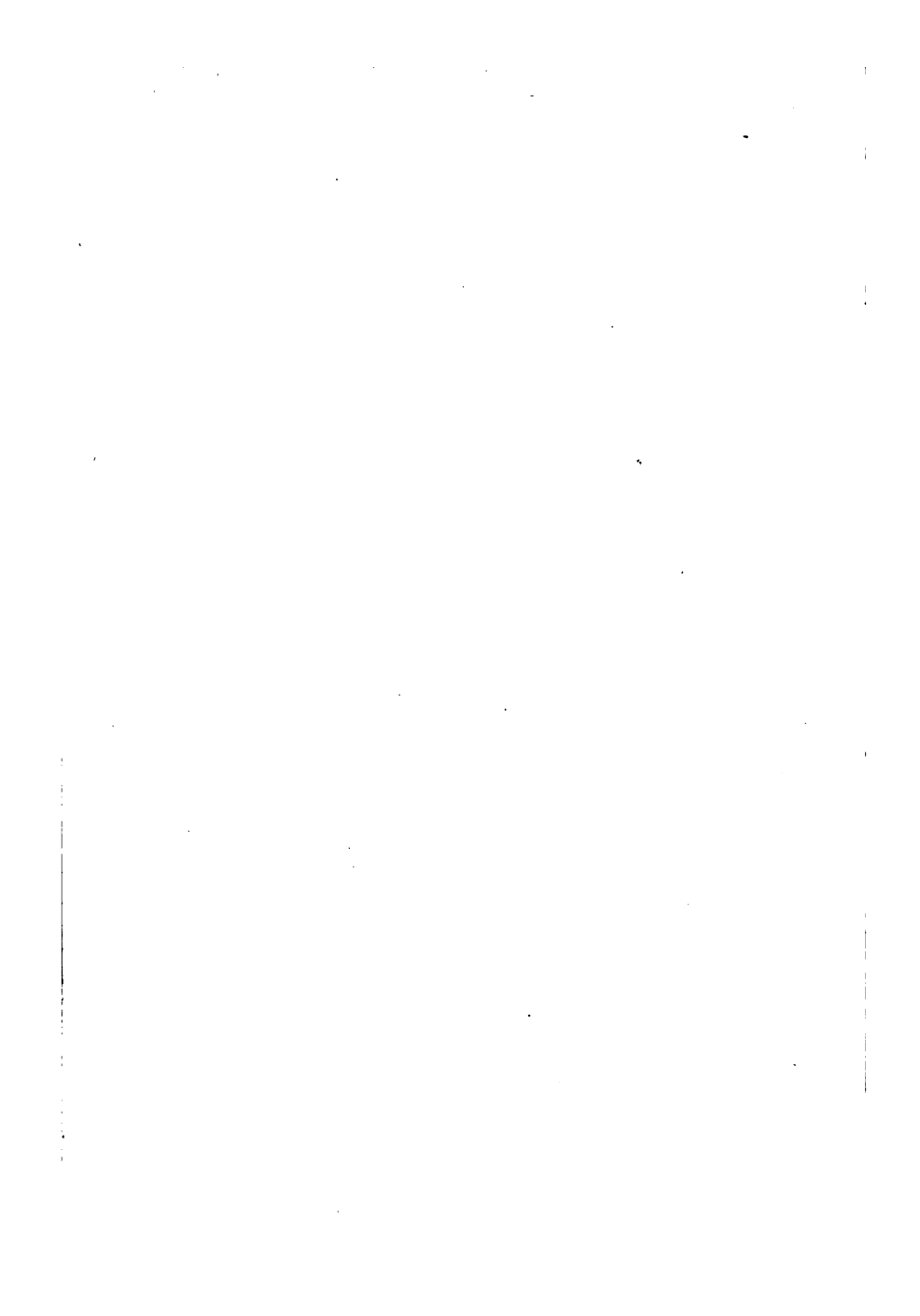
Likewise  $\frac{32 \times 500}{36} = 444·44$  gr. of oxygen.

55·56 gr. of hydrogen occupy a volume of

$$55·56 \times 11·2 = 622·22 \text{ litres.}$$

444·44 gr. of oxygen occupy a volume of

$$444·44 \times \frac{11·2}{16} = 311·11 \text{ litres.}$$



## CHAPTER IV.

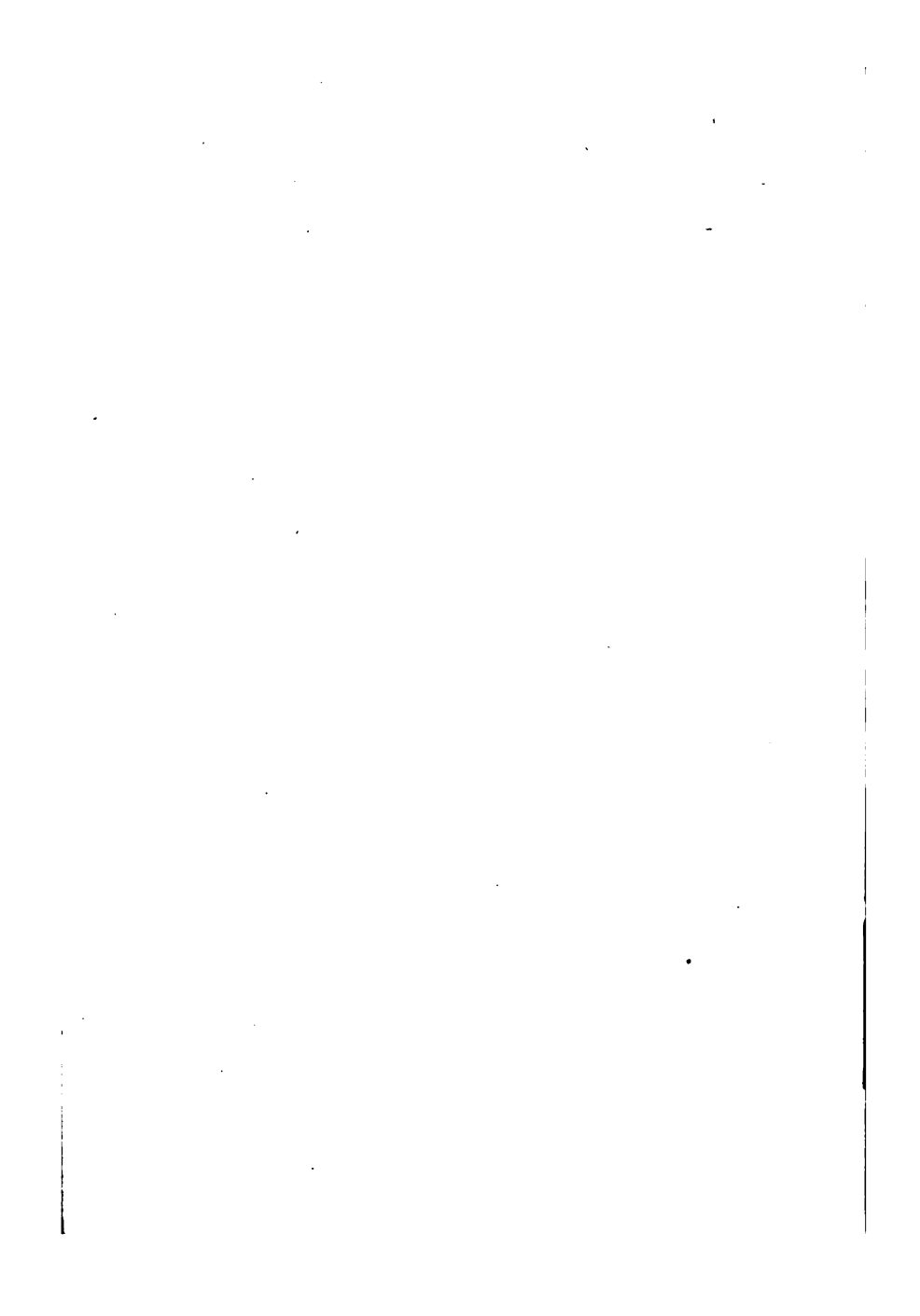
### NITROGEN (N).

(Triad, as in  $\text{NH}_3$ .—Pentad, as in  $\text{NH}_4\text{Cl}$ .)

$$\begin{array}{rcl} (\text{N}_2) \text{ Molecular weight, } 28. & & \\ \hline & = & 14 \text{ sp. gr.} \\ \text{Molecular volume, } & \boxed{1} & \end{array}$$

Or 14 grammes of N measure 11.2 litres.

14 grains of N measure 44.4 cubic inches.



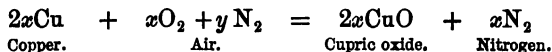
## NITROGEN.

**132.** Name the most important natural substances in which nitrogen is contained. *June 1867.*

Nitrogen exists free in the air, in the proportion of 79 per cent. by volume. It is contained in the native nitrates or nitres, saltpetre or potassic nitrate ( $\text{KNO}_3$ ), and in cubic nitre or sodic nitrate ( $\text{NaNO}_3$ ). It occurs also in coal, and in a few other minerals, and is a constant ingredient of plants and animals. Nitrogen is also found in the East, combined in the salts of ammonia, as in sal-ammoniac.

**133.** How can you obtain pure and dry nitrogen gas from atmospheric air? *June 1876—June 1879.*

I can obtain it pure and dry from the atmospheric air by passing a slow stream of air over copper turnings heated to redness in a tube. The copper combines with the oxygen of the air, forming cupric oxide, and the nitrogen is made to pass into a globe, from which the air has been previously exhausted. The reaction may be represented by the following equation:—



However, to make sure that the gas is dry, and contains no carbonic dioxide ( $\text{CO}_2$ ), I cause it to pass, previously to its passage over the heated copper, through a series of U tubes; some containing fragments

of pumice stone moistened with strong hydric sulphate, in order to deprive the nitrogen of its moisture, if it has any; others containing fragments of potassic hydrate (caustic potash), which causes the gas to part with any carbonic dioxide it may contain.

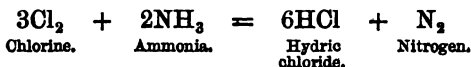
**134.** How do you prepare nitrogen gas? Give an explanation of your process. *June 1866—June 1867.*

I should prepare nitrogen by burning phosphorus in air confined under a globe. This process is undoubtedly the most convenient. I place in a small porcelain dish a small piece of dry phosphorus, and float the dish upon the water in the pneumatic trough; then I kindle the phosphorus by touching it with a hot wire, and I cover it at once with a jar full of air. The phosphorus burns till it has combined with all the oxygen of the air contained in the jar, which becomes filled with white fumes of phosphoric pentoxide ( $P_2O_5$ ). These become gradually dissolved by the water, which during the process rises gradually in the jar, and nearly pure nitrogen is left.

**135.** Give the various processes for obtaining nitrogen. *June 1856.*

1. By depriving the air of its oxygen, thereby leaving the nitrogen free. This may be done by burning phosphorus under a jar filled with air, or by letting a stick of phosphorus stand in it for two or three days, or by passing dry air over red-hot iron or copper, or by moistening iron filings.

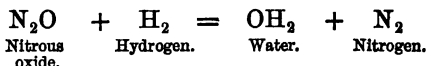
2. By passing chlorine through a solution of ammonia. The chlorine sets free the nitrogen by taking the hydrogen from the ammonia:—



3. By heating a solution of ammonic nitrite. The salt is decomposed into water and nitrogen :—

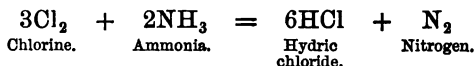


4. By the combination of nitrous oxide with hydrogen. This is accompanied with a detonation.



**136.** You are requested to prepare 1,000 c.c. of nitrogen. Describe how you would do so, and explain your process by means of symbols. *June 1881.*

I should first dissolve 1,000 c.c. of ammonia gas in water; then I should pass through the solution a current of chlorine. The chlorine combines with the hydrogen of the ammonia to form hydric chloride, setting 1,000 c.c. of nitrogen free. The equation of the reaction is :—



This method, however, is not without some danger. Unless the precaution be taken of using an excess of ammonia, there is a possibility of nitric chloride ( $\text{NHCl}_2, \text{NCl}_3$ . ?) being formed, which is of a very explosive character.

**137.** Describe the characters of nitrogen. *July 1856—June 1867.*

Nitrogen is remarkable for its want of all positive properties. It has no effect on litmus paper nor on lime-water. It is not combustible, nor will a taper or ordinary combustibles burn in it; as exceptions, boron and titanium do. Animals are suffocated in nitrogen,

owing simply to the absence of oxygen and not to any poisonous properties of nitrogen. Nitrogen unites with oxygen under the action of the electric spark. It has recently been liquefied by Cailletet. Lastly, it is a little lighter than air, and is slightly soluble in water ( $\frac{1}{30}$ ).

**138.** Describe the mode of distinguishing nitrogen from carbonic acid. *July 1856.*

Show how nitrogen may be distinguished from oxygen, hydrogen, and carbonic dioxide. *June 1867.*

*Nitrogen is distinguished from carbonic dioxide by pouring in the jars containing the gases a small quantity of lime-water ( $\text{CaH}_2\text{O}_2$ ). In the jar containing the carbonic acid the lime-water will become turbid, and a precipitate of calcic carbonate will be formed. On the contrary, when poured in the vessel that contains the nitrogen, the lime-water will remain unchanged. Also carbonic dioxide extinguishes a lighted taper completely and at once, whereas nitrogen does not do so.*

*Nitrogen is distinguished from oxygen by the fact that a match having its point still incandescent is instantly rekindled when plunged into oxygen, whilst, on the contrary, when dipped in the vessel that contains the nitrogen, it soon becomes extinguished.*

*Nitrogen is distinguished from hydrogen by the fact that when a burning taper is applied to the vessel of hydrogen the taper is extinguished, but the gas burns, and when it is applied to the vessel of nitrogen the taper is also extinguished, but the gas does not burn.*

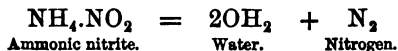
**139.** What effect would an atmosphere of nitrogen produce on life and combustion? *June 1879.*

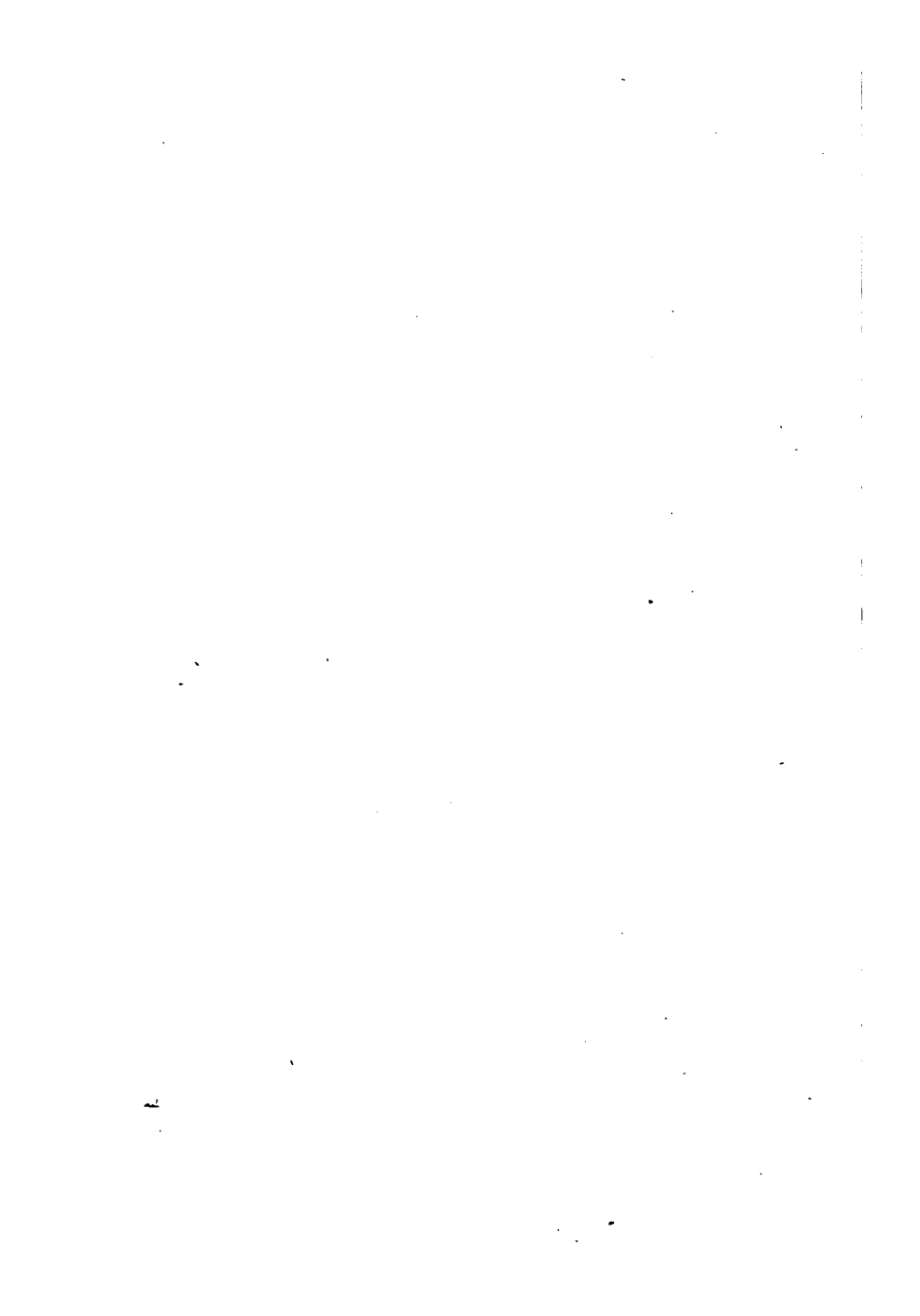
An atmosphere of nitrogen would cause instant

death to all living things, on account of the absence of the oxygen necessary for oxidising the blood; while, in like manner, all combustion would cease.

**140.** Express in symbols what takes place when nitrite of ammonia is subjected to heat. *June 1870.*

If ammoniac nitrite be heated, nitrogen is evolved according to the equation:—





## CHAPTER V.

### THE EARTH'S ATMOSPHERE.

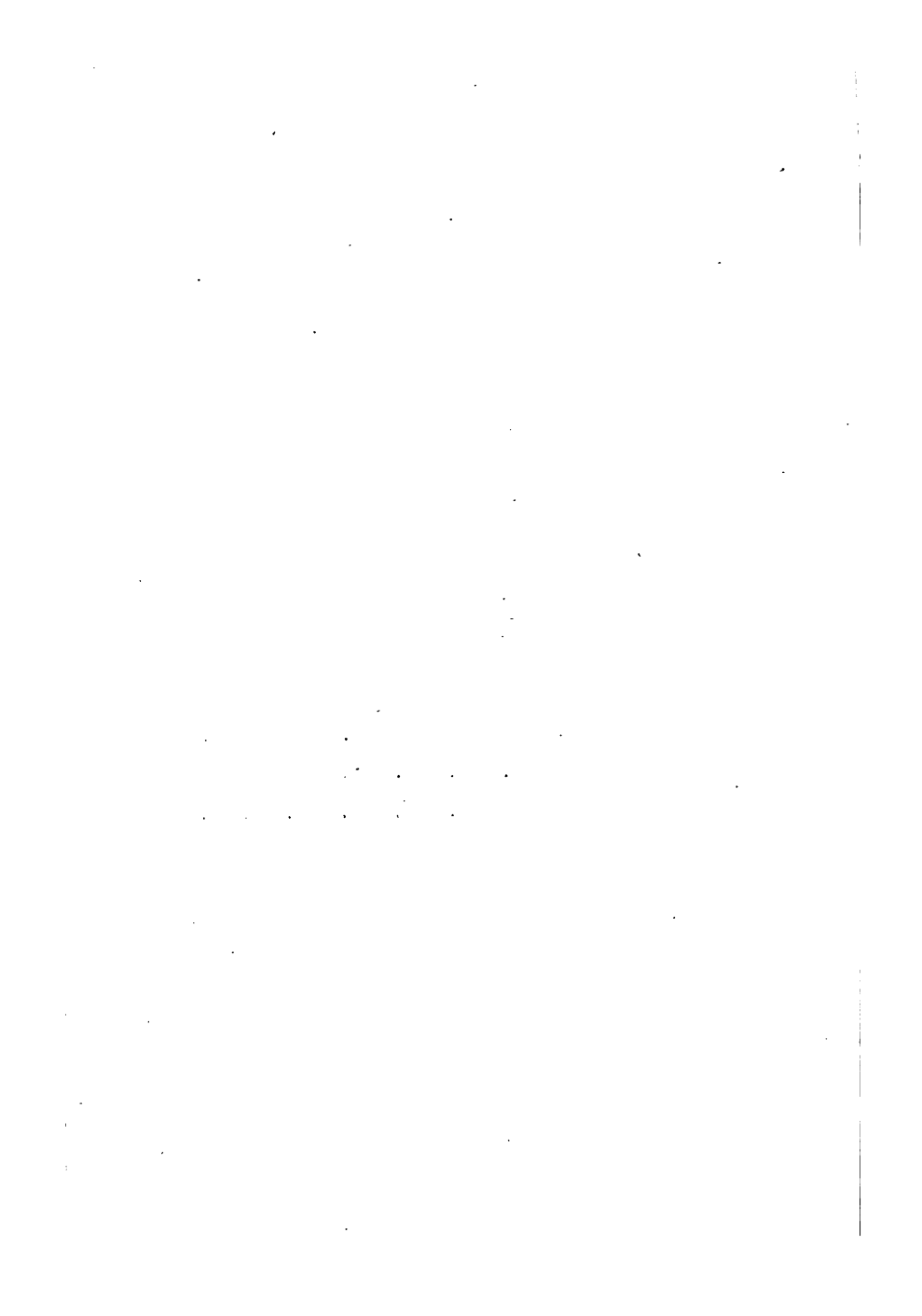
(Air.)

The average composition of the Air in England in 100 parts by volume is :—

Oxygen . . . . .	20·61.
Nitrogen . . . . .	77·95.
Carbonic dioxide . . . . .	·04.
Aqueous vapour . . . . .	1·40.

Or 14·4 grammes of Air measure 11·2 litres.

14·4 grains of Air measure 44·4 cubic inches.



## AIR.

**141.** What are the elementary substances which are **essential** to the constitution of the atmosphere? In what way are they **united together**? *July 1844.*

The elementary substances essential to the constitution of air are **nitrogen** and **oxygen**. They are united together, not as a compound, but as a **mechanical mixture**. Carbonic dioxide, ammonia, and aqueous vapours, although not elementary substances and not essential to animal life, yet are necessary for the growth of plants and trees.

**142.** State the proportions by volume in which nitrogen, oxygen, and carbonic acid gases exist in atmospheric air, and describe the means of chemical analysis by which such information is obtained. *July 1851—July 1863—June 1866.*

**Nitrogen** exists in the air in the proportion of 79 per cent. (by volume).

**Oxygen** exists in the air in the proportion of 21 per cent. (by volume).

**Carbonic dioxide** exists in the air in the proportion of 4 per 10,000.

The proportion by volume of nitrogen and oxygen is obtained by means of the eudiometer, or any graduated tube. As it stands over water introduce into the tube

some air, *say ten inches*, a quantity which will be easily ascertained, since the tube is graduated. Then push up into the confined air of the tube, at the end of an iron wire, a small piece of phosphorus. After a short time all the oxygen will be absorbed by the phosphorus, and the absorption will cause the water within the tube to rise, *say 2 inches*. Thus the space of 2 inches will represent exactly the volume the oxygen occupied. By dividing that space, 2 *inches*, by the former space, 10 *inches*, which the air occupied, it is found to be  $\frac{1}{5}$ , and consequently the nitrogen is  $\frac{4}{5}$  of the volume of air. Thus oxygen constitutes  $\frac{1}{5}$  of the atmosphere and nitrogen  $\frac{4}{5}$ , or 21 per cent. of oxygen for 79 per cent. of nitrogen. To ascertain the amount of carbonic dioxide present in the air, make a large quantity of air pass through a weighed U tube containing a mixture of lime and caustic soda. The increase in weight of the tube is easily obtained by weighing it. Then divide the weight of the air that passed through the U tube by the increase of weight in the U tube, and from the quotient it will be easy to find the percentage.

**143.\*** To what is due the presence of nitrous and nitric acid in the atmosphere, and consequently in rain water?

The presence of each is due to the direct combination of nitrogen with oxygen. The production of nitrous acid is favoured by calm, cloudy weather, a moist atmosphere, and a moderate temperature, whilst a high temperature, dry winds, and thunder storms increase the production of nitric acid (hydric nitrate).

**144.** How is air analysed with a view to determine the proportion of oxygen it contains? *July 1845.*

Whether the proportion of oxygen in air by weight

or by volume is required we are not told. However, we will suppose that we are asked to determine the proportion by weight. If by volume, we refer the reader to Question No. 142. The determination of the composition of oxygen in air by weight is a much more complicated operation than that of the determination of oxygen by volume. However, it may be briefly expressed thus:—Make a known quantity of air, *say* 5.55 grammes, pass over a known quantity of red-hot metallic copper. The oxygen combines with the copper to form cupric oxide, and the increase of the copper in weight shows the exact amount of oxygen contained in the known quantity of air; *say that the increase is* 1.15 grammes.

The nitrogen by itself passes into a glass globe, the weight of which has been accurately ascertained, the air having been previously exhausted. The increase in the weight of the globe, *say* 3.35, is exactly the weight of the nitrogen contained in 5.55 grammes of air.

In order to free from its moisture the air that was to be analysed, it should be made to pass through U-shaped tubes containing pumice stone soaked in oil of vitriol. The increase in weight in these tubes is also ascertained; *say* .5 gramme.

In order to free the air from the carbonic dioxide it contained, it should be made to pass through another pair of U-shaped tubes, containing lumps of solid potash. These combine with the carbonic dioxide, forming potassic carbonate. And again the increase in weight of these tubes is accurately ascertained; *say* .05 gramme.

Thus, to summarise the result:—

$$\begin{array}{rcl}
 & \text{Original weight of air} & + \text{5.55 grammes.} \\
 \text{Weight of moisture and CO}_2 & (\text{.5} + \text{.05}) & - \text{.55} \quad \text{,,} \\
 & & \hline
 & & \text{5 grammes.}
 \end{array}$$

1.15 gramme is the weight of the oxygen, which gives for percentage:—

$5 : 1.15 :: 100 : x = 23$  per cent. of oxygen by weight.

3.85 grammes is the weight of the nitrogen, which give for percentage:—

$5 : 3.85 :: 100 : x = 77$  per cent. of nitrogen by weight.

**145.** One hundred volumes of nitrogen are given. How many volumes of oxygen must be added in order to obtain a mixture of the same composition as pure atmospheric air? *Jan. 1867.*

The composition of air by volume being 79 % of nitrogen and 21 % of oxygen, it follows that  $79 : 21 :: 100 : x$ , or **26.6 volumes of oxygen** have to be added in order to obtain a mixture of the same composition as pure atmospheric air.

**146.** Why is atmospheric air supposed to be a mechanical mixture, and not a chemical compound of oxygen and nitrogen? *Jan. 1865—Jan. 1866.*

The ancients used to consider air as one of the elements. Describe properties of air which cause it no longer to be regarded as an element. *Jan. 1873.*

*Firstly*, because air does not possess properties of its own, different from the mean of the properties of its constituents, oxygen and nitrogen.

*Secondly*, because when air is dissolved in water, if it were a compound, it should dissolve without change of proportional composition. But it does not do so, for the air that is dissolved in water contains a larger proportion of oxygen than it does in the air.

*Thirdly*, because the composition of air varies at different times and places.

*Fourthly*, because a mixture of the constituent gases

in the proper proportions **does not evolve heat**, and has all the properties of atmospheric air.

**147.** The ancients used to consider air to be one of the elements. How would you prove *experimentally* that **air is not a single substance, but a mixture of oxygen and nitrogen**? *Jan. 1875—June 1878.*

How would you prove *experimentally* that the atmosphere is principally composed of a **mixture of oxygen and nitrogen**? *June 1881.*

*Firstly.* I should shake up some air with **potassic pyrogallate**. The liquid becomes of a dark brown colour; the bulk of the air is at the same time diminished, and there remains a gas which is incapable of supporting combustion. The remaining gas is nitrogen, and the oxygen has rendered the potassic pyrogallate of a dark brown colour.

*Secondly.* I should introduce a **stick of phosphorus** in the confined air of a glass jar standing on a trough containing water. After some time the bulk of the air is diminished, as shown by the rising of the water; and the gas that remains is easily proved to be nitrogen. Moreover, this action takes place only where there is free oxygen present; therefore air is composed of oxygen and nitrogen.

*Thirdly.* It is a well-known fact that **nitric oxide** ( $N_2O$ ) **changes into nitrous acid** ( $N_2O_3$ ), with emission of red vapours, as soon as it comes into contact with free oxygen. Now I see it does so when it comes into contact with air; therefore oxygen exists free in air, and is therefore not in a state of combination, but in the state of a mixture.

**148.** What changes take place upon the air inspired by animals? *July 1849—July 1855.*

Explain how the composition of the atmosphere is affected by animal life. *Jan. 1874.*

During the life of an animal combustion of the tissues is continually taking place, these combining with the oxygen and giving off carbonic dioxide and water. The exchange of carbonic dioxide and water takes place during breathing. Thus the air is being continually deprived of oxygen and loaded with carbonic dioxide, and is therefore vitiated through animal life.

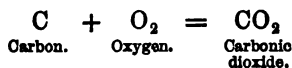
**149.** How is the atmosphere affected by living plants? *July 1855.*

Plants, under the influence of sunlight upon their leaves, have the power of decomposing the carbonic dioxide of the air. The carbon is assimilated, forming other compounds, which constitute the sap, from which are elaborated roots, stem, branches, leaves, and fruit. On the other hand, some of the oxygen is set free. How this decomposition is effected remains still unknown; it is, however, strongly suspected that it is effected mainly by means of the chlorophyll of the leaves, which contains numerous openings, 'stomata,' for the inlet and outlet of the gases. The other green parts of the plants have the same power, but in a very limited degree.

Oxygen also enters plants, dissolved in the water which they absorb by their roots.

**150.** How is the composition of the air affected by its passage over a long layer of red-hot charcoal? *June 1872.*

The oxygen of the air is burned, forming carbonic dioxide :—



At the same time, if this carbonic dioxide has to pass through a long layer of red-hot charcoal, the carbonic dioxide will be reduced in carbonic oxide:—



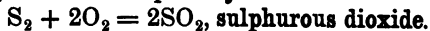
Thus the air has been greatly affected by this passage over the layer of charcoal, since there is **no more free oxygen** present, but merely a mixture of **nitrogen** and the very deleterious gas **carbonic oxide**, and the carbonic acid which escaped deoxidation.

**151.** How is the composition of dry air affected by its passage over of red-hot iron or copper? *Jan. 1866.*

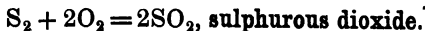
By passing dry air over red-hot iron or copper, the air yields its oxygen, to form with the metals **two oxides**, ferric and cupric oxide. At the same time nitrogen, together with a small amount of carbonic dioxide, passed, unaffected by the heated metals.

**152.** What compounds can be formed by the combustion of the following substances in a limited and in an excessive quantity of air? And what are their respective formulæ? Sulphur, phosphorus, hydrogen, and carbon. *June 1870.*

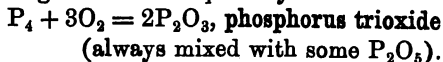
Sulphur burning in a limited quantity of air:—



Sulphur burning in an excess of air:—



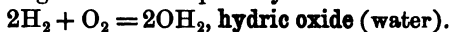
Phosphorus burning in a limited quantity of air:—



Phosphorus burning in an excess of air:—



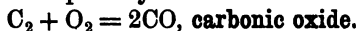
Hydrogen burning in a limited quantity of air:—



Hydrogen burning in an excess of air:—



Carbon burning in a limited quantity of air:—



Carbon burning in an excess of air:—



**153.** Describe the chemical properties of the atmosphere, referring particularly to the nature and proportion of its constituent gases and the uses of each in the economy of nature. *July 1853.*

State the composition of common air, and the purposes which the constituents, comprising those present in minute quantities, subserve in nature. *July 1859.*

The air contains—

**Nitrogen**, which is a colourless, transparent gas, supporting neither life nor combustion. It forms about  $\frac{4}{5}$  of the atmospheric air. In the economy of nature its chief use seems to be to moderate the too violent chemical properties of oxygen.

**Oxygen**, which is a colourless, transparent gas without smell. It forms about  $\frac{1}{5}$  of the bulk of the atmosphere. Its use is, in breathing, to oxidise the blood of animals; in burning, to combine with the carbon and hydrogen of the combustible.

**Carbonic acid**, which is a colourless gas, with no smell, supporting neither combustion nor life, and with slight acid properties. Its purpose in nature is chiefly to afford food for the growth of the tissues of plants and trees. The quantity varies greatly with circumstances, but it is supposed to be about .04 per cent. of the air.

**Ammonia**, which is a transparent and colourless gas.

Its smell is pungent. It possesses strongly the alkali properties—that is to say, to turn to blue the vegetable colours previously turned into red through acids. Its quantity in the air is very small and variable. It is about  $\frac{1}{1000000}$  of the volume of air. Its purpose in nature is to afford to plants and trees nitrogen, which they need to form their seeds and fruit, for it appears that plants have not the power of assimilating the free nitrogen of the atmosphere.

Vapour of water, which is a compound of hydrogen and oxygen in the proportion of 2 : 1. Liquid at the ordinary temperature. Its quantity in the air varies with time and place : it is about 9 or 10 per cent. in weight. Its chief purpose in nature is as a vapour and as rain, to contribute most efficiently to all growth.

**154.** State what change is produced in the air by burning a candle in it. *July 1863—June 1866.*

By burning a candle in the atmosphere the oxygen combines with the carbon and hydrogen to form carbonic dioxide and water. Thus the air will contain a greater proportion of carbonic dioxide and water vapour and less oxygen after the candle has been burning for some time than before. The gas has also become hotter.

**155.** Name the two chief constituents of our atmosphere ; state in what proportions they occur in it ; and give their respective symbols. *Jan. 1868.*

The two chief constituents of our atmosphere are oxygen and nitrogen. They occur in the proportions :—

	Volume.	Weight.
Oxygen . . .	20·8	23
Nitrogen . . .	79·2	77
	<hr/> 100	<hr/> 100

Their respective symbols are O and N.

**156.** How did Lavoisier show the presence of oxygen in air? *June 1866.*

He for several days heated mercury in a closed vessel to nearly its boiling point. At the end of that time the mercury became covered with red scales, increasing at the same time in weight. Then, when he submitted the red powder to a greater heat, the mercury reappeared, a gas, which he called **oxygen**, being given off. Also he proved that the amount of oxygen he collected was exactly the amount lost by the air during the first experiment.

**157.** Describe the chief processes by which oxygen is being removed from the atmosphere. How is it that the ratio of oxygen to nitrogen is nevertheless practically invariable? *June 1865.*

The oxygen is removed from the atmosphere by all kinds of oxidation, such as that in respiration, combustion, germination, and oxidation of metals, chiefly iron.

Practically, however, the ratio of oxygen to nitrogen remains the same, since oxygen is restored mainly from the decomposition of carbonic dioxide by plants and trees. Moreover, the amount of oxygen removed in a limited time from the whole mass of the atmosphere is a very small fraction of it, and the gases being continually mixed by diffusion, the difference is not perceptible.

**158.** How would you show that air is necessary for the maintenance of ordinary combustion? *June 1874.*

I could easily show that air is necessary for the maintenance of ordinary combustion by burning a candle in a closed jar. After a short time, when all the oxygen has been used up, chiefly to form carbonic dioxide, the candle is extinguished.

**159.** What are the chief conditions on which the amount of aqueous vapour in the atmosphere depends? *Jan.* 1874.

*Firstly, the high temperature.* The warmer the air is, the more water it can retain as vapour.

*Secondly, dry air passing over large surfaces of water.* This is the reason why we expect rain when the wind is west, and dry weather when the wind is east.

*Thirdly, the amount of vegetation.* In the neighbourhood of large forests the air is always moister than it would be in a country where there are no woods.

**160.** How is the presence and the quantity of ammonia in the atmosphere ascertained? *July* 1849—*Jan.* 1862—*Jan.* 1866.

The proportion of ammonia in air is far smaller and also more variable than that of carbonic dioxide. The air contains about  $\frac{1}{1000000}$  of its volume of ammonia. It originates chiefly from the decay of vegetable matters and the combustion of coal. A measured quantity of air is passed through distilled water containing a little hydric chloride. This retains the ammonia, which can be estimated by 'Nessler's solution.'

**161.\*** Describe Nessler's test.

This test is used to detect very minute traces of ammonia. One-millionth of the weight of ammonia in water is at once made apparent through the appearance of a brown and yellow precipitate. The test consists of a solution of mercuric iodide in potassic iodide, to which has been added sodic or potassic hydrate until the liquid has become quite clear.

**162.** What are the components of atmospheric air? Describe the properties of its two most abundant constituents, and state how each may be obtained separately. *Jan. 1860—June 1872.*

The components of the atmospheric air are **nitrogen, oxygen, aqueous vapour, carbonic dioxide, ammonia.** The two most abundant constituents of air are **nitrogen and oxygen.**

**Nitrogen** is remarkable for its negative properties, being a colourless, transparent gas, without smell, supporting neither combustion nor life. Yet it is not poisonous of itself, but does not support life by reason of the want of oxygen. It is very little soluble in water.

**Oxygen** is a gas colourless and transparent, without smell, is the great supporter of life and combustion, and is highly soluble in water. It forms compounds with all the elements except fluorine.

The way of obtaining nitrogen separately would be by burning under a glass receiver, over water, a small piece of phosphorus.

The way of obtaining oxygen separately from the air would be by repeating the experiment of Lavoisier, which see. (Question No. 156.)

**163.** Describe the properties of the atmosphere, referring particularly to the rise of vapour, the precipitation of vapour in the form of dew and of clouds and rain, the nature and proportion of the constituent gases of the atmosphere, and their uses in the economy of nature. *July 1846—July 1852—July 1855.*

**Dry air** in contact with water becomes moist, or holds in suspension a quantity of vapour of water, dependent upon its temperature. If a surface in contact with the moist air be cooled below that temperature, the air in

contact with it is also cooled, and can hold the moisture no longer; a part is therefore deposited on the surface as dew. If the moist air itself be cooled below that temperature the moisture is also deposited in small hollow globules of water, and forms a cloud. In the course of time these globules come into contact and coalesce into large drops, which fall as rain.

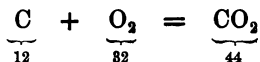
The rest of the question has been answered at length in Nos. 153 and 155.

**164.** The amount of carbonic acid in our atmosphere does not appear to increase. How do you account for this? *Jan.* 1879.

Because it is continually absorbed off by rain and assimilated by trees and plants.

**165.** Supposing the air to contain 23 per cent. of oxygen by weight, how many grains of it must be supplied in order to burn completely (a) 10 grams of carbon, (b) 10 grams of sulphur, (c) 10 grams of phosphorus? (C = 12, S = 32, P = 31). *June* 1875.

Oxygen forms with carbon carbonic dioxide, according to the following equation:—



To burn 12 grammes of C are required 32 of O

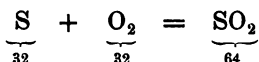
„ 1 gramme of C is „  $\frac{32}{12}$  „

„ 10 grammes of C are „  $\frac{32 \times 10}{12}$

= 26·6 of oxygen,

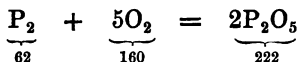
or  $26 \cdot 6 \times \frac{100}{23} = 115 \cdot 65$  grammes of air.

Oxygen forms with sulphur sulphurous dioxide, according to the equation :—



As oxygen and sulphur combine in equal weights, 10 grams of sulphur will require for its combustion 10 grams of oxygen, or  $10 \times \frac{100}{23} = 43.48$  grammes of air.

Oxygen forms with phosphorus phosphoric pentoxide, according to the equation :—



To burn 62 grammes of P are required 160 of O

„ 1 gramme of P „  $\frac{160}{62}$  „

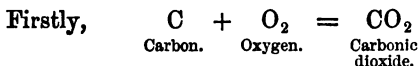
„ 10 grammes of P „  $\frac{160 \times 10}{62}$

= 25.81 of oxygen,

or  $25.81 \times \frac{100}{23} = 112.22$  grammes of air.

**166.** If air contains 23 per cent. of its weight of oxygen, how many lbs. of carbon must be burnt in order to remove all the oxygen from 500 lbs. weight of air? *Jan.* 1878.

The equation representing the combustion of carbon by a limited supply of oxygen of the air is :—



500 lbs. of air contain  $500 \times \frac{23}{100} = 115$  lbs. of oxygen.

Now we say—

To remove 32 lbs. of oxygen I require 12 lbs. of C

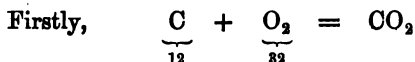
„ 1 lb. „  $\frac{12}{32}$  lb. „

„ 115 lbs. „  $\frac{12 \times 115}{32}$

= 43 lbs. 2 oz. of carbon.

**167. How much air is needed for the complete combustion of 6 grains of pure carbon?** *Jan. 1866.*

First let us find how much oxygen is needed for the complete combustion of 6 grains of pure carbon. The equation representing the reaction is:—



If for the complete combustion of 12 grains of C 32 grains of O are needed, for the complete combustion of 6 grains of C 16 grains of O will be needed; and 16 grains of oxygen represent  $16 \times \frac{100}{23} = 69.56$  grains of air.

**168. How much oxygen is contained in 60 cubic feet of air?** What are the other constituents of air? *Jan. 1864.*

In 60 cubic feet of air there will be 23 per cent. of oxygen.  $60 \times \frac{23}{100} = 13.8$  c. feet 1382 c. inches of oxygen.

The other constituents of air are nitrogen, vapour of water, carbonic dioxide, and traces of other gases, such as ammonia, ammoniacal nitrate, ozone (after storms), and carburetted hydrogen.



# CHAPTER VI.

## COMPOUNDS OF NITROGEN AND OXYGEN.

Nitrous oxide ( $N_2O$ )—

$$\frac{\text{Molecular weight, 44.}}{\text{Molecular volume, } \boxed{\begin{array}{|c|c|} \hline & \\ \hline \end{array}}} = 22 \text{ sp. gr.}$$

Nitric oxide ( $N_2O_2$  or  $NO$ )—

$$\frac{\text{Molecular weight, 60.}}{\text{Molecular volume, } \boxed{\begin{array}{|c|c|} \hline & \\ \hline \end{array}}} = 15 \text{ to } 30 \text{ sp. gr.}$$

Nitric trioxide ( $N_2O_3$ )—

$$\frac{\text{Molecular weight, 76.}}{\text{Molecular volume, } \boxed{\begin{array}{|c|c|} \hline & \\ \hline \end{array}}} = 38 \text{ sp. gr.}$$

Nitric tetroxide ( $N_2O_4$  or  $NO_2$ )—

$$\frac{\text{Molecular weight, 92.}}{\text{Molecular volume, } \boxed{\begin{array}{|c|c|} \hline & \\ \hline \end{array}}} = 23 \text{ to } 46 \text{ sp. gr.}$$

Nitric pentoxide ( $N_2O_5$ )—

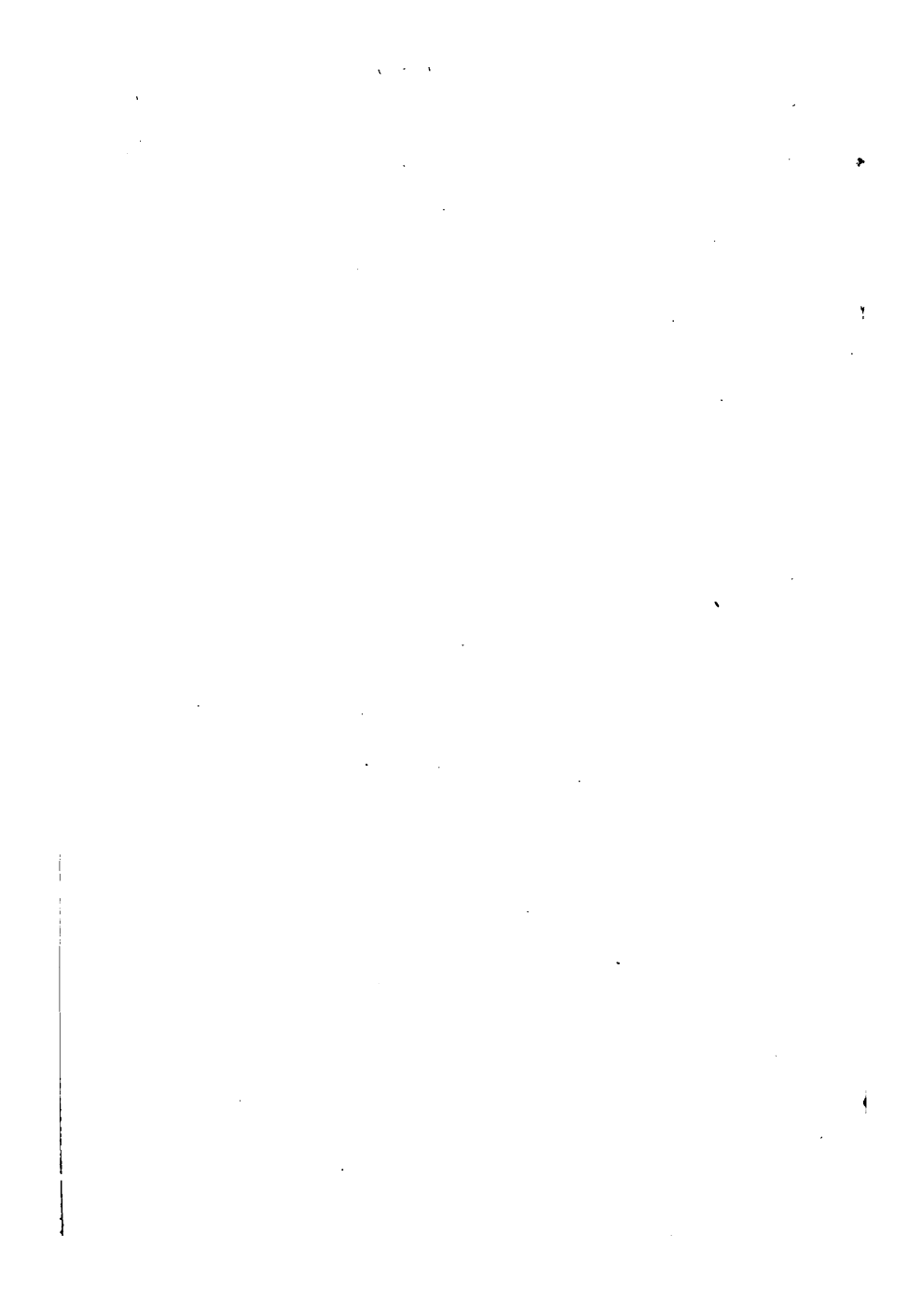
$$\frac{\text{Molecular weight, 108.}}{\text{Molecular volume, } \boxed{\begin{array}{|c|c|} \hline & \\ \hline \end{array}}} = 54 \text{ sp. gr.}$$

Or 22 grammes of  $N_2O$ , 38 of  $N_2O_3$ , 54 of  $N_2O_5$  measure 11·2 litres.

22 grains of  $N_2O$ , 38 of  $N_2O_3$ , 54 of  $N_2O_5$  measure 44·4 c. ins.

Or 15 grammes of  $N_2O_2$ , 23 of  $N_2O_4$  (at a high temp.), and 30 of  $N_2O_2$ , 46 of  $N_2O_4$  (at a low temp.) measure 11·2 litres.

15 grains of  $N_2O_2$ , 23 of  $N_2O_4$  (at a high temp.), and 30 of  $N_2O_2$ , 46 of  $N_2O_4$  (at a low temp.) measure 44·4 c. inches.



## NITROUS OXIDE.

**169.** Enumerate the compounds which nitrogen forms with oxygen. Give the symbol and combining number of each. *July 1854—Jan. 1861.*

Give the names and formulæ of the oxides of nitrogen, and calculate their percentage composition. *June 1870.*

Compounds of N with O.	Formulæ.	Combining numbers.	Percentage composition.	
			N.	O.
Nitrous oxide <sup>1</sup>	$N_2O$	44	68·63	36·27
Nitric oxide	$N_2O_2(NO)$	60(30)	46·66	53·34
„ trioxide	$N_2O_3$	76	36·84	63·16
„ tetroxide	$N_2O_4(NO_2)$	92(46)	30·43	69·57
„ pentoxide	$N_2O_5$	108	25·93	74·07

**170.** Calculate the density of nitrous oxide ( $N_2O$ ) at  $0^\circ$  C. and 760 m.m. pressure.

[Atomic weight of oxygen = 16.

„ „ nitrogen = 14.] *Jan. 1879.*

$N_2O = 2 \times 14 + 16 = 44$ , representing 2 volumes.  
Hence 1 volume, or its density compared to hydrogen, will be—

$$\frac{44}{2} = 22.$$

**171.** What are the principal acid compounds of nitrogen and carbon with oxygen? *July 1846.*

<sup>1</sup> The names are those adopted by Roscoe.

The principal acid compounds are :—

**Hydric nitrite** ( $\text{HNO}_2$ ), formed from nitric trioxide ( $\text{N}_2\text{O}_3$ ) in the presence of water.

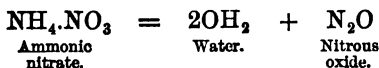
**Hydric nitrate** ( $\text{HNO}_3$ ), formed from nitric pentoxide ( $\text{N}_2\text{O}_5$ ) in the presence of water.

**Hydric carbonate**, in solution ( $\text{H}_2\text{CO}_3$ ), formed from carbonic dioxide ( $\text{CO}_2$ ) in the presence of water.

**172.** Express in symbols what takes place when nitrate of ammonia is subjected to heat. *Jan.* 1862—*June* 1870.

Describe how you would prepare nitrous oxide. *July* 1852—*June* 1874.

When ammonic nitrate, after having been placed in a retort, is subjected to heat, the white crystals melt to a clear fluid. After a slight elevation of temperature it is entirely decomposed into nitrous oxide and water. The water condenses, and the nitrous oxide may be collected in a jar placed on the pneumatic trough. The following equation represents the reaction :—



**173.** Give the properties of nitrous oxide. *Jan.* 1862.

Nitrous oxide is a colourless, invisible gas, possessing a faint agreeable odour and a pleasant, sweetish taste. It dissolves in its own volume of water. Like oxygen, it is a great supporter of combustion. It is distinguished from oxygen by its greater solubility in water, and its taste, but principally by producing no dark brown fumes when mixed with nitric oxide, and by causing sulphur to burn therein with a beautiful

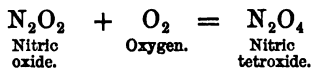
rose tint. It is used as an anæsthetic, because it produces insensibility to pain under surgical operations. Davy gave to it the name of laughing gas, on account of the peculiar excitement it causes on some persons when inhaled.

**174.** Describe the properties by which you would distinguish nitrous oxide (laughing gas) from a mechanical mixture of 2 volumes of nitrogen and 1 volume of oxygen. *June 1871.*

How would you distinguish nitrous oxide from oxygen? *June 1874.*

Describe how you would ascertain by experiments whether a gas composed of 1 volume of nitrogen and 1 volume of oxygen is a mechanical mixture or a chemical compound of the two elements. *Jan. 1881.*

I should introduce into both jars a few bubbles of nitric oxide ( $N_2O_2$ ). In the jar containing the nitrous oxide ( $N_2O$ ) the bubbles of nitric oxide would remain unaffected; but in that containing the mixture of nitrogen and oxygen, or pure oxygen, they at once would assume a dark brown colour and turn into nitric tetroxide:—



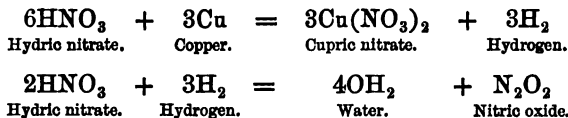
And, again, I should pour into both jars some potassic pyrogallate, which would absorb the gas, and turn to a darker hue in the jar containing the free oxygen, but not so in that containing the nitrous oxide.

Finally, a stick of dry phosphorus introduced into the jar containing the free oxygen would begin to give off white fumes and absorb the gas, but it would not do so in that containing the nitrous oxide.

## NITRIC OXIDE.

**175.** Give the names and chemical formulæ of the substances formed by the action of hydrogen nitrate (nitric acid) upon metallic copper. What happens when the gas produced in this reaction comes into contact with air? *Jan. 1861—June 1869.*

When diluted hydric nitrate is poured over copper clippings or filings contained in a retort, or into a hydrogen bottle, without the application of heat, nitric oxide is formed, which may be collected at the pneumatic trough. The reaction seems to be twofold. First, the hydrogen is expelled from the hydric nitrate and replaced by the copper; then the liberated hydrogen combines with the oxygen of another molecule of the acid to form water, while the nitrogen and the rest of the oxygen of this molecule are evolved in combination as nitric oxide gas. This double reaction may be represented thus:—

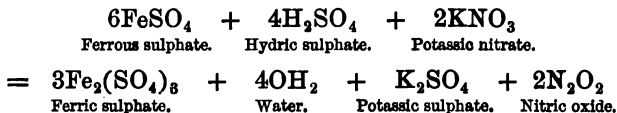


**176.** Describe the various ways of preparing nitric oxide. *July 1852.*

One of the modes of preparation has been given in the preceding number.

It may also be prepared by gently heating in a flask a produced mixture of potassic nitrate ( $\text{KNO}_3$ ) and ferrous sulphate ( $\text{FeSO}_4$ ), with the addition of diluted

hydric sulphate. The reaction may be represented by the following equation :—



In order to prevent the frothing up at the beginning of the experiment, a little sand should be added to the mixture.

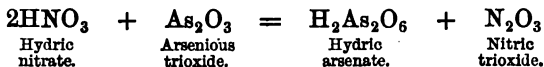
**177.** What are the properties of nitric oxide?  
*June 1861.*

Nitric oxide is colourless and invisible, slightly heavier than air, but little soluble in water, incombustible, and not a supporter of respiration and of ordinary combustion. The most useful property of this gas is that, in the presence of free oxygen, it gives rise to the production of red vapours of nitric tetroxide ( $\text{N}_2\text{O}_4$ ), affording thereby a delicate test for the presence of free oxygen.

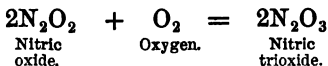
### NITRIC TRIOXIDE.

**178.\*** How is nitric trioxide prepared?

It is prepared by gently heating hydric nitrate with arsenious trioxide or with starch :—



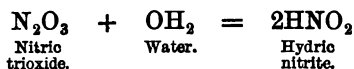
It may also be prepared by mixing 4 measures of nitric oxide ( $\text{N}_2\text{O}_2$ ) with 1 measure of oxygen :—



Precaution should be taken to cool the mixture to  $-18^{\circ}\text{C}$ . The two gases combine to form red fumes, which condense to a volatile indigo-blue coloured liquid by a cold of  $-30^{\circ}\text{C}$ .

**179.\*** What are the properties of nitric trioxide ?

The properties of this substance are not remarkable. Only when dissolved in water it forms an acid called hydric nitrite :—



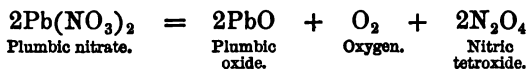
This acid is the type of the series of salts called nitrites, chiefly noticeable for the readiness with which they give up or absorb oxygen.

Thus an acidified solution of potassic nitrite bleaches one of potassic permanganate by a reducing action, but it bleaches a solution of an aniline dye by an oxidising action.

## NITRIC TETROXIDE.

**180.\*** How is nitric tetroxide procured ?

It is most easily procured by heating lead nitrate ( $\text{PbNO}_3$ )<sub>2</sub> in a glass tube. Deep red fumes are given off. These fumes may, at a low temperature, be condensed into a red liquid, and, if quite free from water, may even be obtained in crystals. The equation representing the reaction is :—



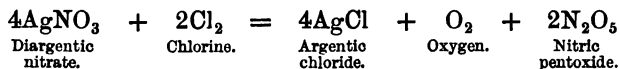
**181.** Give a brief description of the characteristic properties of nitric tetroxide ( $\text{N}_2\text{O}_4$ ). *Jan.* 1881.

Nitric tetroxide is a **red gas**, which is easily liquefied when condensed, and which crystallises when submitted to a low temperature. In the liquid state it assumes a **yellowish colour** at the ordinary temperature, and when cooled to  $-18^{\circ}$  C. it becomes colourless. Again, by a mere trace of water the liquid becomes **green**; then, by addition of more water, drop by drop, the liquid turns **dark blue** at first and then colourless, it being decomposed into nitric oxide and hydric nitrate.

### NITRIC PENTOXIDE.

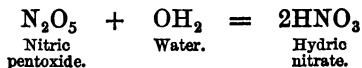
**182.** Describe the **properties** and **preparation** of nitric pentoxide. *July 1852.*

It cannot be prepared directly from hydric nitrate, but it may be obtained by **passing dry chlorine over dry argentic nitrate** ( $\text{AgNO}_3$ ). Argentic chloride is formed, oxygen is given off, and a white crystalline substance is produced, which on analysis is found to be nitric pentoxide:—



It forms transparent, colourless crystals, which melt at  $30^{\circ}$  and boil at  $45^{\circ}$  C.

It combines rapidly with water, forming a corrosive liquid called hydric nitrate:—





## CHAPTER VII.

### HYDRIC NITRATE.

(Nitric acid—Aqua fortis.)

$$\frac{\text{Molecular weight, 63.}}{\text{Molecular volume, } \boxed{\phantom{00}}\boxed{\phantom{00}}} = 31\cdot5 \text{ sp. gr.}$$

Or 31·5 grammes of  $\text{HNO}_3$  measure 11·2 litres.

31·5 grains of  $\text{HNO}_3$  measure 44·4 cubic inches.



## HYDRIC NITRATE.

**183.** Calculate the **percentage composition** of nitric acid ( $N = 14$ ,  $O = 16$ ,  $H = 1$ ). *June 1877.*

$$H = 1 \quad . \quad . \quad \frac{1 \times 100}{63} = 1.59 \text{ of hydrogen.}$$

$$N = 14 \quad . \quad . \quad \frac{14 \times 100}{63} = 22.22 \text{ of nitrogen.}$$

$$O_3 = \frac{48}{63} \quad . \quad . \quad \frac{48 \times 100}{63} = \frac{76.19}{100.00} \text{ of oxygen.}$$

**184.** What is the **common mode** of preparing nitric acid? *July 1849—Jan. 1863.*

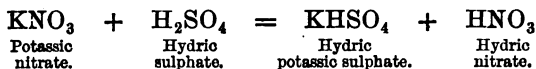
**Explain** by means of symbols the formation of nitric acid from saltpetre and common sulphuric acid. *Jan. 1872—Jan. 1879.*

**Explain the reaction** which takes place when you add hydric sulphate to potassic nitrate. *July 1856—July 1861—June 1880.*

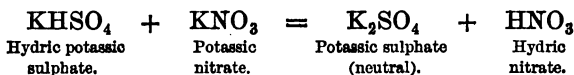
The most ready way of obtaining hydric nitrate is to prepare it either from potassic or sodic nitrate ( $NaNO_3$ ).

A mixture of saltpetre ( $KNO_3$ ) and oil of vitriol ( $H_2SO_4$ ) is introduced in a glass retort, to which gentle heat is applied. Red fumes make their appearance in the retort both at the beginning and at the end of the operation, arising from a partial decomposition of the acid and the formation of some of the lower oxides of nitrogen, which give to the hydric nitrate its

peculiar yellow tint. The vapours of hydric nitrate are received in the receiver flask, which is cooled by a stream of cold water, in order to cause the condensation of the vapours. The reaction is represented thus :—



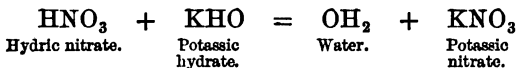
By addition of *more* potassic nitrate, and by application of greater heat, the potassium of the potassic nitrate may be replaced by the hydrogen of the hydric potassic sulphate :—



In other words, if only half the former quantity of hydric sulphate is used, and the temperature increased, more hydric nitrate may be obtained, and at less cost.

**185.** What happens when hydric nitrate is added to a solution of potassic hydrate? *July 1847—Jan. 1872—Jan. 1879.*

When hydric nitrate is placed in contact with a solution of potassic hydrate, a **violent action takes place** if the solution be concentrated, in which the hydrogen of the acid is replaced by the potassium of the hydrate.



The result would be the same if the solution of potassic hydrate were weak, only the reaction would be accompanied by no violence.

**186.** Describe the composition and properties of nitric acid. *July 1849—July 1856—July 1861.*

The composition of hydric nitrate is expressed by the formula  $\text{HNO}_3$ , viz. the molecule of hydric nitrate consists of 1 atom of H, 1 of nitrogen, and 3 of oxygen.

Hydric nitrate is a colourless and transparent liquid when pure; if not pure, it has a yellowish tint. It has a peculiar odour, a very sour taste, and is exceedingly corrosive. The skin is destroyed and made yellow by it. On this account it is used, in a diluted state, to colour silk and woollen goods. It fumes in the air when concentrated. Finally, it is a **great oxidising agent**, and therefore bleaches indigo and oxidises metals. It is also a **great solvent**; it dissolves nearly all the metals, but it has no action upon gold, platinum, rhodium, and iridium.

**187.** You prepare hydrogen by the action of zinc upon diluted sulphuric acid. **Why cannot hydrogen be procured by the action of zinc upon dilute nitric acid?**  
*Jan. 1872.*

The reason is because **hydric nitrate is a very powerful oxidising agent**. On account of that property the hydrogen, as soon as produced, is at once oxidised; that is to say, combines with the oxygen originating from the decomposition of hydric nitrate to form water. The remainder of the molecule of the hydric nitrate goes to form some oxides of nitrogen, or ammonia, the compound formed depending on the state of dilution of the acid. In the first reaction there would remain in the jar zincic sulphate ( $\text{ZnSO}_4$ ), and in the second zincic nitrate ( $\text{ZnN}_2\text{O}_6$ ).

**188.** What are the distinguishing tests of nitric acid? *July 1856—July 1861.*

1. The blue colour of indigo is destroyed by hydric nitrate.

2. Red fumes ( $N_2O_4$ ) are given off when the acid, diluted, is poured over copper filings.

3. A brownish red ring is formed at the line of contact when hydric sulphate has been carefully poured over the hydric nitrate mixed with ferrous sulphate.

**189.** What is the difference between a nitrate and a nitrite? Jan. 1871—Jan. 1879—Jan. 1882.

*The difference in composition is that a nitrate contains 3 atoms of oxygen, while the nitrite only contains 2.*

*The difference in their formation is that a nitrate is formed by the substitution of a metal for the hydrogen in hydric nitrate ( $HNO_3$ ), and a nitrite is formed by the substitution of a metal for the hydrogen in hydric nitrite ( $HNO_2$ ).*

**190.** Calculate the percentage composition of saltpetre from the formula  $KNO_3$  ( $K = 39$ ,  $N = 14$ ,  $O = 16$ ). June 1879.

$$K = 39 \quad . \quad . \quad \frac{39 \times 100}{101} = 38.61 \text{ of potassium.}$$

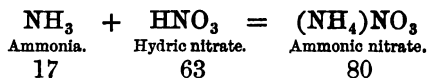
$$N = 14 \quad . \quad . \quad \frac{14 \times 100}{101} = 13.86 \text{ of nitrogen.}$$

$$O_3 = \frac{48}{101} \quad . \quad . \quad \frac{48 \times 100}{101} = \frac{47.53}{100.00} \text{ of oxygen.}$$

**191.** If 126 grains of nitric acid (hydric nitrate) were neutralised with ammonia gas, what weight and what properties would the new compound have? Jan. 1876.

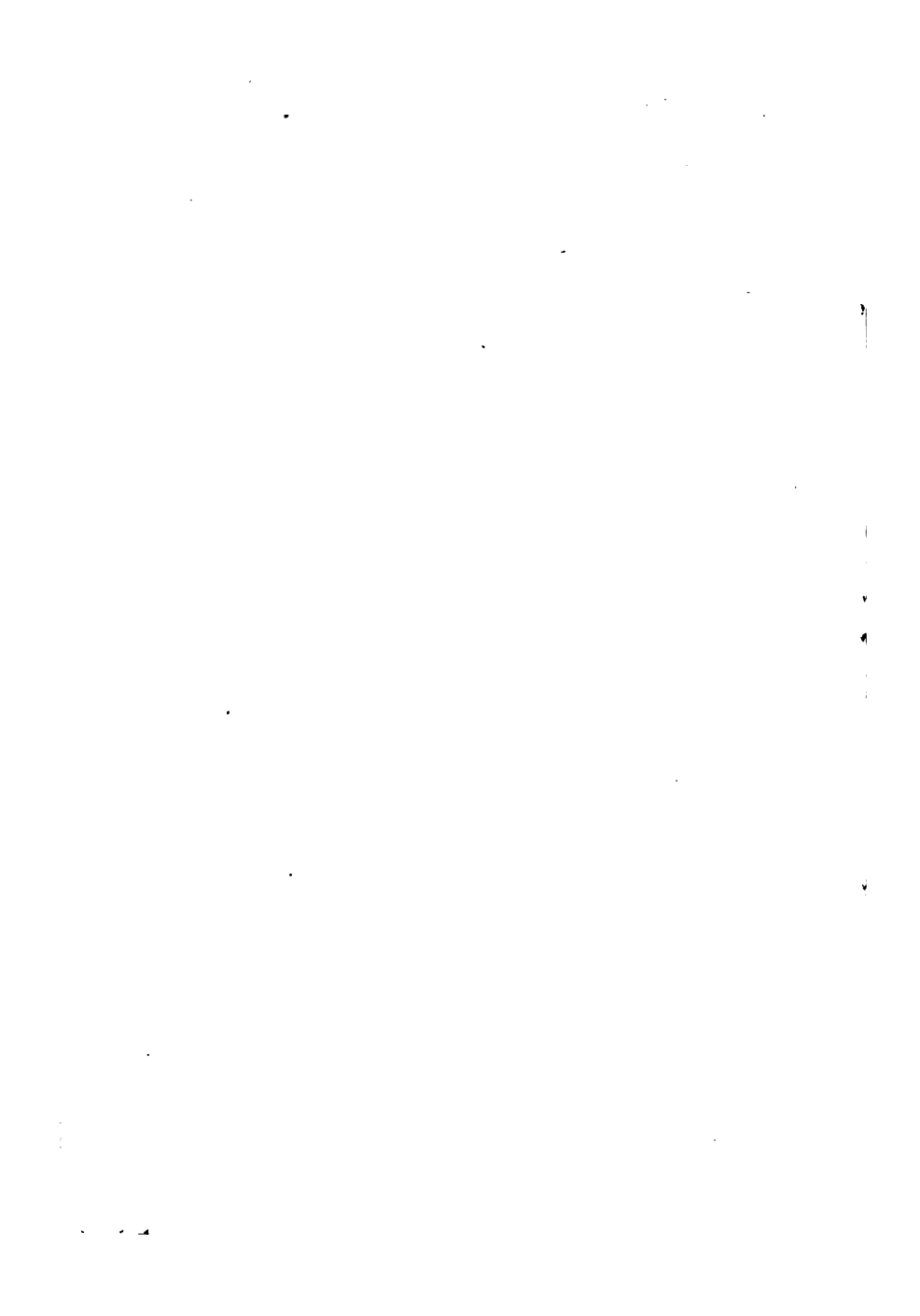
Ammonia gas combines with all hydrogen salts or

acids. Thus it combines with hydric nitrate, as may be seen by the following equation :—



Thus the new compound consists of white crystals of ammonic nitrate, which are very soluble in water, but deprived of all acid properties. When heated, it is resolved into water and laughing gas ( $\text{N}_2\text{O}$ ).

As the ammonia gas combines with one molecule or 63 grains of hydric nitrate to form 1 molecule or 80 grains of ammonic nitrate,  $2 \times 63$  or 126 grains of hydric nitrate will form  $2 \times 80 = 160$  grains of ammonic nitrate.



## CHAPTER VIII.

### AMMONIA ( $\text{NH}_3$ ).

(Trihydric nitride--Volatile alkali--Spirits of hartshorn.)

$$\frac{\text{Molecular weight, 17.}}{\text{Molecular volume, } \boxed{\begin{array}{|c|} \hline 1 \\ \hline \end{array}}} = 8.5 \text{ sp. gr.}$$

Or 8.5 grammes of  $\text{NH}_3$  measure 11.2 litres.

8.5 grains of  $\text{NH}_3$  measure 44.4 cubic inches.



## AMMONIA.

**192.** The molecule of ammonia consisting of one atom of nitrogen and three atoms of hydrogen, what is the density of ammonia on the hydrogen scale? *Jan. 1873—Jan. 1881.*

The formula of ammonia is  $\text{NH}_3$ , the molecular weight 17, representing 2 volumes of ammonia. Consequently the density of ammonia on the hydrogen (H) scale will be  $\frac{17}{2} = 8.5$ .

**193.** Give the composition of ammonia by weight and by volume. *July 1852—July 1857—July 1862—Jan. 1863—Jan. 1865.*

The composition of ammonia ( $\text{NH}_3$ ) by weight is 14 grains, grammes, or tons, &c., of nitrogen, and 3 grains, grammes, or tons, &c., of hydrogen.

The composition of ammonia by volume is 1 pint, litre, or cubic inch, &c., of nitrogen, and 3 pints, litres, or cubic inches, &c., of hydrogen.

**194.** It is asserted that one molecule of ammonia consists of one atom of nitrogen and three atoms of hydrogen. What do we mean by an atom of nitrogen? Calculate the percentage composition of ammonia. *Jan. 1868.*

By one atom of nitrogen we mean the smallest amount of nitrogen that can enter into combination. Nitrogen is said to be a triad in ammonia, because 1

atom of nitrogen enters into combination with 3 of hydrogen.

The percentage composition of ammonia is :—

$$\text{N} = 14 \quad . \quad . \quad \frac{14 \times 100}{17} = 82.36 \text{ of nitrogen.}$$

$$\text{H}_3 = \frac{3}{17} \quad . \quad . \quad \frac{3 \times 100}{17} = \frac{17.64}{100.00} \text{ of hydrogen.}$$

**195.** Describe how you would prove that ammonia is a compound of hydrogen and nitrogen. *Jan. 1881.*

I should pass a series of electric sparks through ammonia gas contained in a tube over mercury, which causes the ammonia to decompose into hydrogen and nitrogen. That **free hydrogen is contained in the tube** I prove by introducing into the tube oxygen gas until the electric spark ceases to combine; that the result of this combination is water I prove by the fact of its being a liquid with no action on litmus paper and setting a piece of potassium on fire: thus **ammonia contains hydrogen**. Finally, that free nitrogen is contained in the tube I prove by the fact that it **extinguishes a lighted taper** and does not render lime-water milky on being shaken up with it: thus **ammonia contains nitrogen**.

**196.** What are the sources of ammonia? *July 1857.*

The Arabs obtained it first by heating the dung of camels. This operation was performed in the vicinity of the temple dedicated to Jupiter Ammon: hence its name 'ammonia.' The putrefaction of all animal and vegetable substances containing nitrogen is another source of ammonia. Ammonia is also formed in considerable quantities during the distillation of bones and of animal

**refuse generally.** The horns of harts were at first thought to be the best material for preparing ammonia; from this fact it was called spirits of hartshorn. Nowadays, however, ammonia and its compounds are chiefly obtained from the ammoniacal liquors of the gas works. Ammonia also is found in the atmosphere, and also in clayey and in peaty soils, both of which absorb it freely.

**197. How is ammonia obtained?** *July 1857—July 1860—Jan. 1863—Jan. 1865.*

**Give the process for preparing ammoniacal gas from sal ammoniac.** *July 1852—July 1862.*

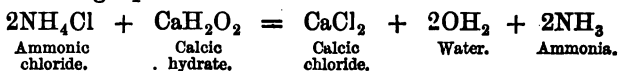
**Describe the preparation of ammonia from ammoniac chloride (sal ammoniac), and explain your process by means of symbols.** *June 1868.*

**Explain by an equation the process of making ammonia by the action of slaked lime upon sal ammoniac.** *Jan. 1870—Jan. 1873.*

Ammonia is often prepared by expelling it through gentle heat from the liquid ammonia in which it is present in solution in great quantity.

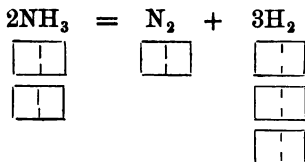
But the ordinary way of preparing it is from the sal ammoniac, the formula of which is  $\text{NH}_4\text{Cl}$ . To procure the ammonia from this salt it is only necessary to take away the hydric chloride. This is done by any strong base, such as slaked lime or caustic soda.

The powdered sal ammoniac is introduced into a flask together with its own weight of slaked lime. Then heat is gently applied, and a colourless gas is given off, which may be collected either over mercury or by upward displacement. The reaction may be expressed by the following equation:—



**198.** What bulk of each of its constituent gases would be furnished by a cubic inch of ammonia, supposing it completely decomposed by a series of electric sparks? *Jan. 1863.*

The constituent gases of ammonia are: **nitrogen** and **hydrogen**, combined by volume in the proportion of 1 is to 3. This may be clearly seen from the following diagram:—



That is to say that

4 volumes of  $\text{NH}_3$  produce 2 volumes of N and 6 volumes of H.

$\therefore$  1 cubic inch of  $\text{NH}_3$  produces  $\frac{2}{4}$  or  $\frac{1}{2}$  inch of N and  $\frac{6}{4}$  or  $1\frac{1}{2}$  inch of H.

**199.** Enumerate the principal properties of ammonia. *July 1852—July 1857—Jan. 1870—Jan. 1873.*

Ammonia is a colourless gas, possessing a strong, pungent, and peculiar smell, most characteristic of this gas. It has a caustic taste, and blisters the skin if applied to it in a concentrated form. It is lighter than air, its density being .59. Hence it may be collected by upward displacement. It may be collected over mercury, but never over water, which dissolves about 1,150 times its volume of gas at the standard pressure and temperature. This gas, dissolved in water, constitutes the *spirits of hartshorn*, the *liquor ammoniæ* of the apothecary, and the *ammonia* of the chemist. It possesses a strong alkaline reaction, turning red vegetable colours blue. It has also strong basic properties, that

is to say, it unites with most acids, forming the ammoniacal salts. The gas under the pressure of about 7 atmospheres and at the ordinary temperature ( $15^{\circ}\text{C}.$ ) condenses into a colourless liquid.

It produces first a **green precipitate**, and afterwards, on the addition of more ammonia, a **beautiful purple-blue solution with salts of copper**. It is irrespirable, and **extinguishes** a lighted taper.

**200.** Describe how you would illustrate experimentally the basic properties of ammonia. *June 1879.*

By **basic property** is meant the property of acting on the *acid*, thus that the hydrogen of the acid be replaced by the metal of the base to form either a *neutral salt*, if all the hydrogen has been replaced, or an *acid salt*, if the hydrogen has been but partly replaced. Now the ammonia, which is really an ammoniac hydrate ( $\text{NH}_4\text{OH}$ ), possesses this property in an eminent degree. The group  $\text{NH}_4$ , called ammonium, is looked upon by chemists as constituting a metal similar in its chemical properties to potassium.

To illustrate the basic properties of ammonia I should proceed in the following ways:—

1. I should pour some ammonia on a red solution of litmus. This solution turns blue.

2. I should pour ammonia into hydric sulphate until the mixture affects neither red nor blue litmus. The acid has been neutralised, and a salt, ammoniac sulphate, has been formed.

Or I should fill two wide-mouthed bottles, one with hydric chloride gas, the other with ammonia gas. As soon as they are brought into contact, dense white fumes are formed, which in a short time condense against the cold walls of the bottles, assuming the

appearance of a snowy white powder. This powder is ammoniac chloride, and dissolved in water it has no effect upon either the red or blue litmus.



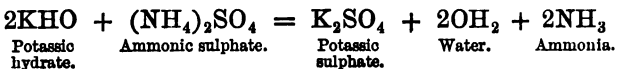
**201.** Ammoniac gas is passed (a) into water, (b) into dilute sulphuric acid. Describe in detail what takes place. How can the gas be obtained from both these solutions? *Jan.* 1877.

(a) If ammonia gas is passed into water, it forms a solution known under the various names of liquid ammonia, or ammonia spirits of hartshorn, liquor ammoniac, or volatile alkali.

To obtain from this solution the ammonia gas contained in it, it is sufficient to apply gentle heat to the liquid.

(b) If ammonia gas is passed into dilute hydric sulphate it forms a neutral salt of ammoniac sulphate,  $(\text{NH}_4)_2\text{SO}_4$ .

To obtain from this substance the ammonia contained in it, mix it with potassic hydrate or slaked or quick lime, then place it in a flask and heat it gently. The potassic hydrate acts as follows:—



and ammonia is set free.

**202.** Give an account of the composition, preparation, and properties of the alkalies potash and soda. What compounds do these alkalies form when mixed with hydrochloric, sulphuric, and nitric acids? *July* 1847—*July* 1853.

The alkalis potash and soda have for composition  $\text{KHO}$ ,  $\text{NaHO}$  respectively.

They are both prepared by decomposing the carbonate ( $\text{K}_2\text{CO}_3$  and  $\text{Na}_2\text{CO}_3$ ) with calcic hydrate or slaked lime.

Both are white substances, very deliquescent, and soluble in water.

Their solution possesses in the highest degree the properties termed *alkaline*. It restores the blue colour to litmus paper which has been reddened by an acid, and neutralises the most powerful acids.

Both dissolve skin and many other organic matters. Surgeons frequently use caustic potash as a cautery. Both, if exposed to the air, absorb the carbonic dioxide to form potassic carbonate ( $\text{K}_2\text{CO}_3$ ) or sodic carbonate ( $\text{Na}_2\text{CO}_3$ ); hence they should be kept in closely stopped bottles.

Mixed with hydric chloride, potash forms potassic chloride ( $\text{KCl}$ ), and soda forms sodic chloride ( $\text{NaCl}$ ).

Mixed with hydric sulphate, potash forms potassic sulphate ( $\text{K}_2\text{SO}_4$ ), and soda forms sodic sulphate ( $\text{Na}_2\text{SO}_4$ ). 4

Mixed with hydric nitrate, potash forms potassic nitrate ( $\text{KNO}_3$ ), and soda forms sodic nitrate ( $\text{NaNO}_3$ ).

**203.** How would you test an aqueous solution for hydric chloride ( $\text{HCl}$ ), hydric sulphate ( $\text{H}_2\text{SO}_4$ ), and ammonia ( $\text{NH}_3$ ) respectively? Jan. 1881.

To test a solution of hydric chloride, I should pour into it a few drops of **argentic nitrate**, when a white precipitate is formed which is insoluble in hydric nitrate and soluble in ammonia.

To test a solution of hydric sulphate, I should pour into the solution a few drops of **baric chloride**, when a

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white precipitate is formed which is insoluble in hydric nitrate.

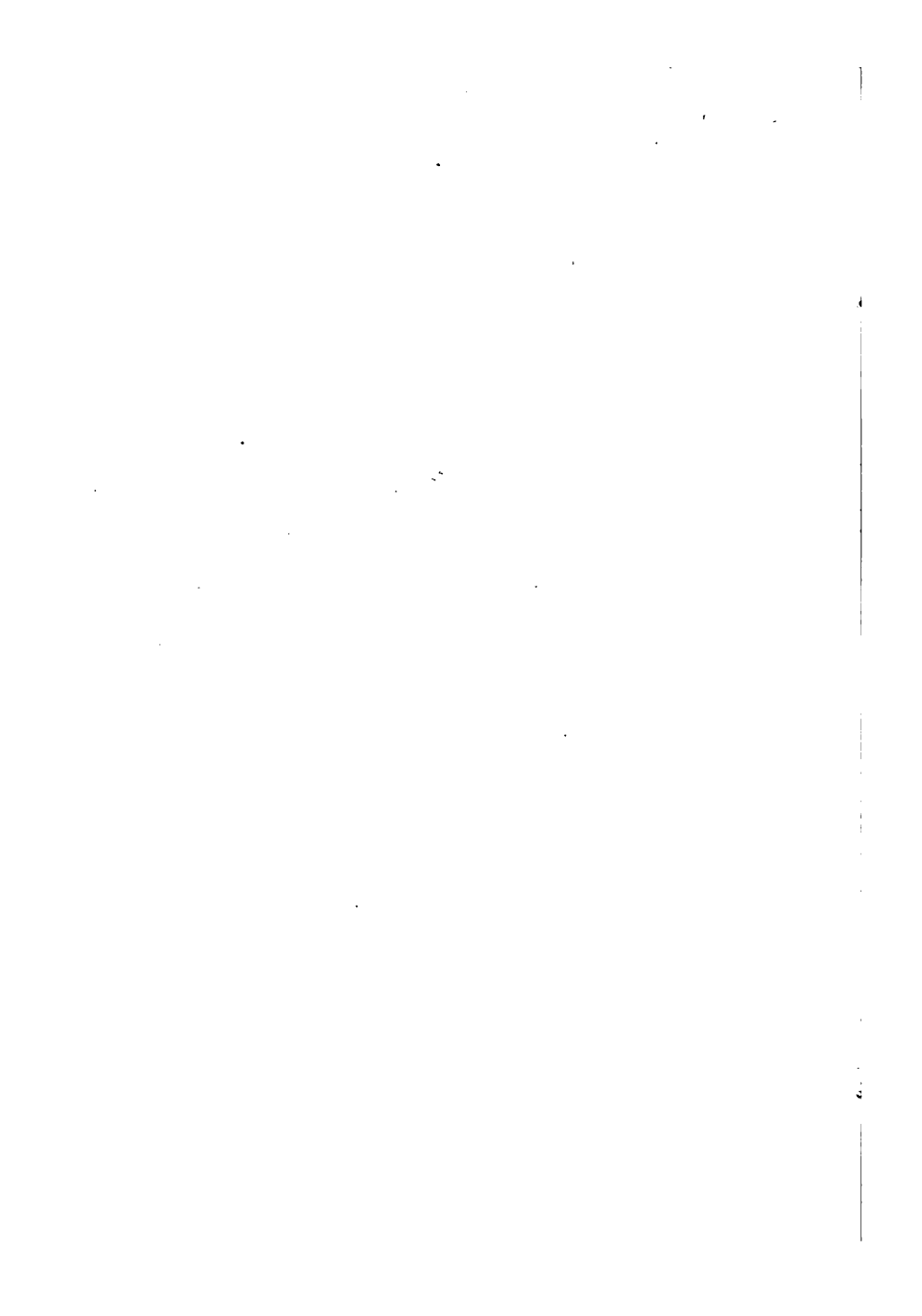
Finally, to test a solution of ammonia, I should pour into the solution a few drops of **potassic** ( $\text{KHO}$ ) or **sodic hydrate** ( $\text{NaHO}$ ), and apply heat. The vapour that comes off renders moist red litmus paper blue. But the most delicate test of ammonia would be to **mix it with lime and gently heat the mixture**. A glass rod dipped in dilute hydric chloride and held over the mixture would cause the appearance of dense white fumes of ammoniac chloride.

## CHAPTER IX.

### CARBON (C).

(Dyad, as in CO—Tetrad, as in CO<sub>2</sub> and CH<sub>4</sub>.)

Atomic weight=12.



## CARBON.

**204.** Describe some of the principal forms of carbon. *Jan.* 1863.

1. **Diamond** is the purest representative of carbon. Its density is 3·5. It is the hardest body known. It crystallises in forms belonging to the cubic system, and is found native in the alluvial soils of India and Brazil. It is much valued as a gem on account of its hardness and transparency, and high refractive power for light. It is used to cut glass. Burned in oxygen it produces carbonic dioxide.

2. **Graphite**, or plumbago, which is often, but improperly, called black lead, is much used in the manufacture of pencils. Like diamond it is found native in various parts of the world, crystallised in forms belonging to the hexagonal system, also in masses. It is very soft, black with a metallic lustre, a good conductor of heat and electricity.

3. **Charcoal** is of two kinds—wood charcoal, originating from the distillation of wood in iron retorts; and animal charcoal, originating from the distillation of bones, also in iron retorts. Both are black, and are remarkable for the property of absorbing enormous quantities of gases, and of removing colour from liquids which owe their tint to the presence of organic matters. This property, however, is chiefly remarkable in the animal charcoal. Thus it is that wood charcoal is chiefly used for purifying and aerating water, and

the animal charcoal for bleaching and disinfecting purposes.

4. **Coke** is the residue left in the retorts used for making coal gas. It is porous, hard, and possessed of a slight metallic sound. It is used for purposes of heating furnaces, and has the advantage of giving great heat and no smoke.

5. **Soot** is condensed smoke, deposited in chimneys. It is used as a manure on account of the ammonia it contains.

6. **Lampblack** is obtained by burning bodies rich in carbon, such as impure turpentine, in a limited supply of air. It is chiefly used in the fabrication of printer's ink.

**205.** What proof would you give that diamond is carbon? *Jan. 1882.*

I should plunge the diamond into a vessel containing oxygen, after having heated it to bright redness in a cage of platinum wire; the diamond would burn with a steady red light, with the production of carbonic dioxide.

I should then do the same with a piece of carbon, say charcoal, which also produces a gas which is recognised to be carbonic dioxide by the fact of its rendering lime-water milky. Thus carbon is diamond, and diamond is carbon.

**206.** Carbon is said to exist in three allotropic modifications. Describe why diamond, graphite, and charcoal are considered to be modifications of the element carbon. *June 1864—June 1873—June 1880.*

If diamond (see preceding number), graphite, and charcoal are placed in hard glass tubes, and heated to

redness, and oxygen passed over them, they combine with the oxygen, forming a gas which, passed over lime-water, produces the same milky precipitate of calcic carbonate ( $\text{CaCO}_3$ ).

**207.** Under what condition is diamond changed into graphite? *Jan.* 1882.

When the diamond is introduced into the flame of the voltaic arc, it undergoes a remarkable change. At white heat the diamond begins to swell up, loses its transparency, and is converted into a black opaque mass, resembling graphite, or better coke.

**208.** A solid substance is suspected to contain some compound of carbon. How would you ascertain by experiment whether such is the case? *Jan.* 1870.

Carbon may exist either as a carbonate or in some other form. If then a few drops of hydric chloride be poured over the suspected body, and a gas be given off, which, passed through lime-water, causes it to become milky or turbid, then the suspected body contains carbon and exists as a carbonate. But if no change takes place in the lime-water, mix the body with lime, and heat the mixture in a tube, and then, if the gas evolved causes the lime-water to become turbid, the suspected body contains carbon. If, however, even so no action takes place, then the suspected body contains no carbon.

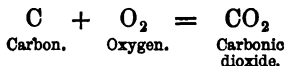
**209.** What elements can be made to combine with carbon directly? *Jan.* 1882.

Oxygen and sulphur at a high temperature are the only substances that combine directly with carbon. Berthollet, however, has found by experiment that by

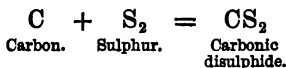
igniting charcoal intensely by means of the voltaic arc in a current of pure hydrogen, a compound of hydrogen and carbon, named acetylene ( $C_2H_2$ ), is formed.

**210.** What is the action of oxygen and of sulphur separately upon red-hot charcoal? *Jan.* 1877.

1. If the oxygen be in excess, then carbonic dioxide is formed according to the equation :—

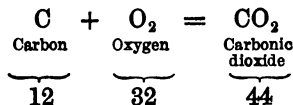


2. If sulphur is made to pass over red-hot charcoal, a compound is formed which is a liquid of a most unpleasant smell—namely, carbonic disulphide :—



**211.** How much carbon could be completely burned by a ton of air? *June* 1867.

In a ton of air there is contained 23 % of oxygen, or  $\frac{2240 \times 23}{100} = 515\frac{1}{2}$  lbs. of oxygen. Now carbon burned in oxygen produces carbonic dioxide according to the following equation :—



$\therefore$  32 lbs. of oxygen burn 12 lbs. of carbon

1 lb. „ burns  $\frac{12}{32}$  lb. „

$\therefore$   $515\frac{1}{2}$  lbs. „ burn  $\frac{12 \times 515\frac{1}{2}}{32}$

$= 193\frac{1}{2}$  lbs. of carbon.

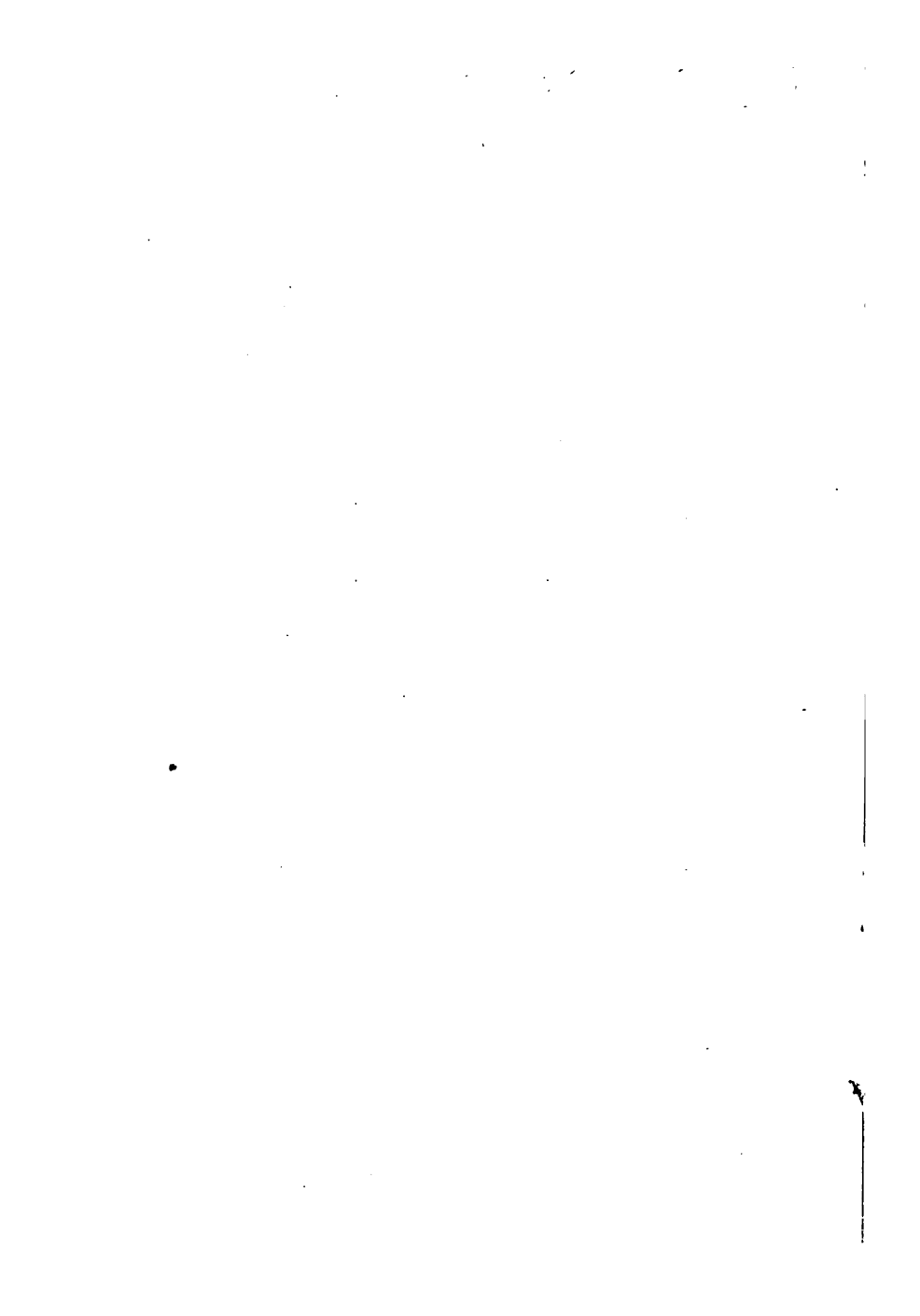
## CHAPTER X.

### CARBONIC OXIDE (CO).

$$\frac{\text{Molecular weight, 28.}}{\text{Molecular volume, } \boxed{2}} = 14 \text{ sp. gr.}$$

Or 14 grammes of CO measure 11.2 litres.

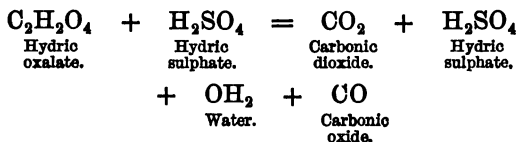
14 grains of CO measure 44.4 cubic inches.



## CARBONIC OXIDE.

**212.** How is carbonic oxide prepared in a state of purity? *July* 1863.

Carbonic oxide is prepared in the laboratory by heating crystallised hydric oxalate with concentrated hydric sulphate ( $\text{H}_2\text{SO}_4$ ). The formula of oxalic acid (hydric oxalate) is  $\text{C}_2\text{H}_2\text{O}_4$ , which contains the elements of carbonic dioxide, carbonic oxide, and water, as is seen when written thus:  $\text{CO}_2, \text{CO}, \text{OH}_2$ . The hydric sulphate breaks up the hydric oxalate into these three compounds, but remains itself undecomposed. This reaction may be represented by the following equation:—

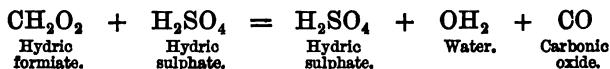


In order to get rid of the carbonic dioxide, pass the resulting gas through a solution of caustic soda, which absorbs the carbonic dioxide, forming with it sodic carbonate.

**213.\*** Give another method of obtaining this gas.

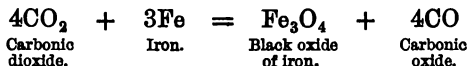
Another method of obtaining the gas is by decomposing similarly formic acid or hydric formiate ( $\text{CH}_2\text{O}_2$ , or  $\text{CO}, \text{OH}_2$ ). Upon application of heat the

hydric sulphate causes the separation without undergoing decomposition itself, according to the equation :—



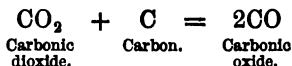
**214.** Describe an experiment by which you would prepare carbonic oxide gas from carbonic acid. *June 1869.*

A current of dry carbonic dioxide is made to pass through a long tube containing fragments of charcoal or iron turnings at a bright red heat. Precaution must be taken to pass the gas through a bottle containing pumice-stone soaked in a strong solution of caustic soda (NaHO), in order to absorb the portion of carbonic dioxide which always remains unreduced. The reaction may be expressed by the following equation :—



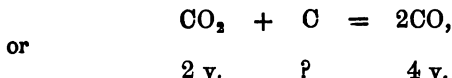
**215.** What gaseous body results from passing carbonic acid over red-hot charcoal? *July 1863.*

When carbonic dioxide is passed over red-hot charcoal, carbonic oxide (CO) is formed, which may be expressed thus :—



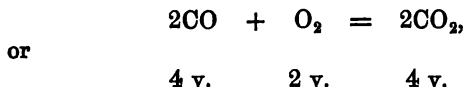
**216.** A litre of carbonic acid is completely reduced to carbonic oxide by hot carbon. What volume of carbonic oxide is obtained? What volume of oxygen is needed for the complete combustion of this carbonic oxide? *Jan. 1870.*

The reaction of the reduction may be expressed thus:—



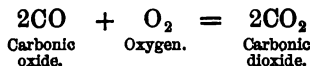
Thus 4 volumes of carbonic oxide are obtained, *i.e.* 2 litres.

For the complete combustion of these 4 volumes of carbonic oxide are required 2 volumes, *i.e.* 1 litre, of oxygen, as may be gathered from the equation of the reaction:—



**217.** Give an account of the composition and properties of carbonic oxide gas. *July 1850—July 1854.*

Carbonic oxide is a colourless, invisible gas, without taste or smell, and scarcely soluble in water. It is very poisonous, and does not support combustion, but burns with a bright blue flame, producing carbonic dioxide:—

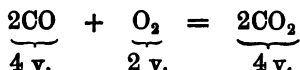


It is a powerful reducing agent; for if carbonic oxide be passed over heated ferric oxide ( $\text{Fe}_2\text{O}_3$ ), or cupric oxide ( $\text{CuO}$ ), the carbonic oxide changes into carbonic dioxide, and the metal, iron or copper, remains.

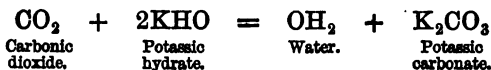
Carbonic oxide is composed of carbon and of oxygen. Its composition by weight is 12 of carbon and 16 of oxygen. When mixed with half its volume of oxygen, carbonic oxide combines, with detonation and with formation of carbonic dioxide.

**218.** A gaseous mixture, consisting of 100 volumes of carbonic oxide and 150 volumes of oxygen, is confined over mercury. An electric spark is passed through the mixture, and a ball of caustic potash is then brought into the gas. Describe the chemical changes which occur, and state what volume (if any) of gas remains at the end of the operation. *June 1875.*

The electric spark causes the carbonic oxide and oxygen to combine :—



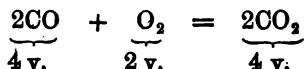
forming carbonic dioxide, and, as in the chemical action the quantity of carbonic oxide is double to that of oxygen, there remains 100 volumes of oxygen free and uncombined, in addition to the 100 volumes of  $\text{CO}_2$ . Then upon the introduction of the ball of caustic potash ( $\text{KHO}$ ), the carbonic dioxide combines, forming potassic carbonate ( $\text{K}_2\text{CO}_3$ ) in the shape of a white powder :—



At the end of the operation there still remain 100 volumes of uncombined oxygen.

**219.** How many volumes of carbonic oxide and of oxygen respectively are required for the production of 75 cubic centimetres of carbonic acid ( $\text{CO}_2$ )? *June 1873.*

The reaction may be expressed by the following equations :—



There will be required 75 cubic centimetres of carbonic oxide and  $37\frac{1}{2}$  cubic centimetres of oxygen.

**220.** Two bottles, one containing carbonic oxide and the other anhydrous carbonic acid, are given you to determine the nature of the gas in each bottle. **Describe the experiments** you would perform for this purpose. *Jan. 1873.*

I should be able to recognise at once which of the two jars contains the carbonic dioxide by pouring into both a few drops of lime-water. The bottle in which, after shaking it a little, the lime-water becomes milky, contains the carbonic dioxide; the other, in which no change takes place, contains the carbonic oxide.

Again, I should present a light successively to the two bottles. If the light be instantly extinguished, I know that the bottle I presented it to contains the carbonic dioxide; if, on the contrary, it causes the gas to burn with a bright blue flame, I know that the bottle contains the carbonic oxide.



## CHAPTER XI.

### CARBONIC DIOXIDE ( $\text{CO}_2$ ).

(Carbonic Anhydride—Carbonic Acid.)

$$\frac{\text{Molecular weight, 44.}}{\text{Molecular volume, } \boxed{\quad}} = 22 \text{ sp. gr.}$$

Or 22 grammes of  $\text{CO}_2$  measure 11.2 litres.

22 grains of  $\text{CO}_2$  measure 44.4 cubic inches.



## CARBONIC DIOXIDE.

**221.** How much heavier is carbonic dioxide than hydrogen? *Jan.* 1866.

Since its s.g. compared to hydrogen is  $44 : 2 = 22$ , that means to say that carbonic dioxide is **22 times heavier** than hydrogen.

**222.** What is the composition of carbonic acid? *Jan.* 1861.

What gaseous compounds does carbon form with oxygen? Give the composition of each. *July* 1846—*Jan.* 1863.

The gaseous compounds of carbon with oxygen are:—

1. **Carbonic oxide** ( $\text{CO}$ ), consisting of 1 atom or 12 parts of carbon for 1 atom or 16 parts of oxygen.

2. **Carbonic dioxide** ( $\text{CO}_2$ ), consisting of 1 atom or 12 parts of carbon for 2 atoms or 32 parts of oxygen.

**223.** Why is carbonic dioxide commonly called carbonic acid? *Jan.* 1879.

If sulphurous, sulphuric, phosphoric oxides ( $\text{SO}_2$ ,  $\text{SO}_3$ ,  $\text{P}_2\text{O}_5$ ) are termed acids, then carbonic dioxide ( $\text{CO}_2$ ) is properly termed an acid, for it has similar chemical properties; each **changes the colour** of moistened blue litmus paper to red; each, when added to a solution of a base, **combines with it**, forming a salt, and each may displace the others from its com-

pounds; thus baric carbonate and sodic sulphate become baric sulphate and sodic carbonate, and on boiling the process is reversed.

**224.** State the principal natural sources of carbonic acid. *July 1845—July 1849—July 1854—Jan. 1860—July 1860—June 1861—Jan. 1869.*

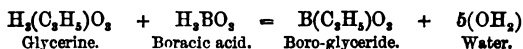
By what processes is carbonic acid generated in nature? *Jan. 1873.*

The principal natural sources of carbonic dioxide are:—

1. The volcanoes.
2. The escape of the gas from fissures of the earth, as that of the 'Grotto del Cane,' near Naples.
3. Some mineral waters, such as those of Seltz.
4. Combustion.
5. Respiration of animals and of plants in the absence of sunlight.
6. Fermentation of wine or beer.
7. Putrefaction<sup>1</sup> and decay of organic matter.
8. Germination, natural and artificial, as in the manufacture of malt.

**225.** By what natural agency is the carbonic acid constantly entering the atmosphere withdrawn, and its

<sup>1</sup> 'Putrefaction and decay of animal matter is always connected with, and probably dependent upon, the growth of the microscopic fungi known as *bacteria*.' The object of antiseptics is to prevent the growth of these fungi. Professor Barff, in a paper read by him before the Society of Arts (March 1882), announces that he has discovered an antiseptic which he has proved by many experiments to be highly successful. He calls it the 'boro-glyceride'—a compound formed by the action of boracic acid on glycerine. The equation of the reaction seems to be:—



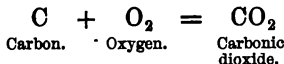
injurious accumulation prevented? *July 1845—July 1849—July 1854.*

**226.** Mention the causes which tend to keep down the amount of carbonic acid of our atmosphere. *Jan. 1869.*

The enormous quantity of carbonic dioxide, were it to accumulate in the atmosphere, would soon cause the death of all animals. But this, fortunately, does not happen. The greatest portion of it goes to **produce vegetable growth**. The carbonic dioxide coming in contact with the green leaves, under the influence of daylight, is **decomposed into oxygen**, which returns to the atmosphere, and **carbon**, which is assimilated by the plant. Its injurious accumulation is also checked, but to a smaller extent, **by the rain**. Water is able to dissolve about once its volume of carbonic dioxide. The rain water, thus holding in solution a certain amount of carbonic dioxide, is then able to dissolve salts of calcium, which by their combination constitute the great source of the carbonates found in nature.

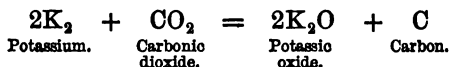
**227.** How would you prove that carbonic acid consists of carbon and oxygen? *June 1865.*

First, I should prove it *synthetically*, i.e. by burning a piece of **carbon in oxygen**. The result of the combustion is found to be carbonic dioxide:—

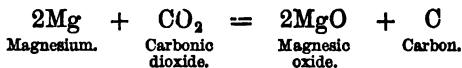


Secondly, *analytically*. That carbonic dioxide contains oxygen and carbon I should prove by the following experiment:—I put a small piece of the metal called **potassium** in a flask containing carbonic dioxide.

I heat this carefully. The potassium decomposes the carbonic dioxide, forming potassic oxide ( $K_2O$ ) and setting free the carbon, which forms a black deposit on the sides of the flask.



But a more practical experiment would be the following:—Heat a piece of magnesium wire coiled into a spiral until it burns, and then plunge it into the jar containing the carbonic dioxide. The magnesium continues to burn for some time in the gas. A white powder, magnesian oxide (magnesia), is produced, together with black flakes of carbon, which are deposited on the sides of the jar.

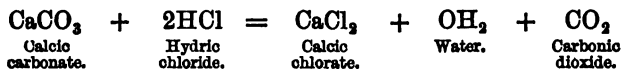


**228.** Describe briefly the preparation of carbonic acid. *July 1847—July 1844—July 1860—June 1861—June 1865—Jan. 1868.*

How is carbonic acid obtained in a state of purity? *July 1863—Jan. 1866.*

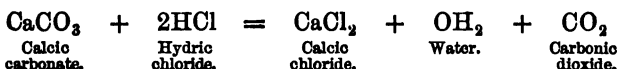
Pure carbonic dioxide is prepared by the action of hydric chloride on some more or less pure forms of native calcic carbonate ( $CaCO_3$ ), such as marble, chalk, or limestone. The operation is performed in an apparatus such as is used for the preparation of hydrogen. The carbonate is immersed in water, and hydric chloride ( $HCl$ ) is slowly added to it. A brisk effervescence is immediately set up, and a gas comes off which can be collected by downward displacement. The

whole reaction may be represented by the following equation :—



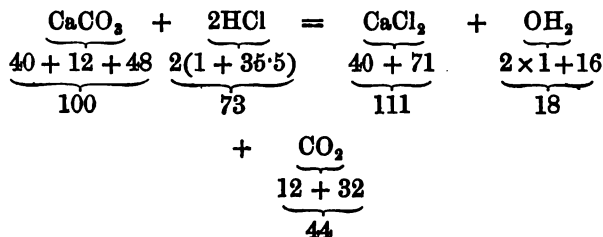
**229.** Express in symbols the action which takes place between hydrochloric acid and chalk; and describe in words the changes which occur, and the proportions by weight of each constituent. *July 1856—July 1859.*

The action that takes place may be represented by the following equation :—



What occurs is this : The metal of the carbonate, *i.e.* the calcium, is replaced by the hydrogen of the hydric chloride, forming hydric carbonate ( $\text{H}_2\text{CO}_3$  or  $\text{OH}_2\text{CO}_2$ ). But this compound cannot long exist under these conditions, and therefore breaks up in  $\text{CO}_2$  and  $\text{OH}_2$ . The calcium that was ejected from the calcic carbonate or chalk ( $\text{CaCO}_3$ ) combines with the chlorine of the decomposed hydric chloride to form calcic chloride.

The proportion by weight of each constituent is :—



**230.** Describe the physical and chemical properties of carbonic acid. *July 1856.*

Describe briefly the properties of carbonic acid. *July 1847—July 1849—July 1860—June 1861—June 1865—Jan. 1868.*

According to its physical properties, carbonic dioxide is a colourless and invisible gas, 22 times heavier than hydrogen. It is generally believed to be inodorous, but has a slightly acid taste. Its action on litmus paper is very faint, changing its blue tint for that of port-wine. Water dissolves its own volume of carbonic dioxide.

Chemically considered, carbonic dioxide is not combustible, nor is it a supporter of combustion. However, metals such as potassium and magnesium burn in it, at the same time decomposing the gas and leaving the carbon deposited on the sides of the flask. The chlorophyll (or green) of the leaves under the influence of daylight decomposes it. It is poisonous, but indirectly, on account of the absence of air. It renders clear lime-water at once milky.

**231.** Describe the properties of carbonic acid in the solid, liquid, and gaseous form. *Jan. 1860—July 1863.*

In the gaseous form. These have been given in the preceding number.

In the liquid form. Carbonic dioxide may be liquefied by the application of a pressure of 36 atmospheres, or by cooling the gas to a very low temperature. Liquid carbonic dioxide is a colourless and a very mobile liquid. It boils at  $-78^{\circ}\text{C}$ .

In the solid form. At a still lower temperature it freezes to a colourless, ice-like solid. This happens as soon as the liquid is brought out to the open air, when

it begins to evaporate so rapidly as to freeze the remainder into a white solid, looking very much like snow. The solid carbonic dioxide can be taken up by the hand with impunity; but the liquid carbonic dioxide, in coming into close contact with the skin, produces blisters very similar to that produced by a burn.

**232.** By what experiment is the presence of carbonic acid gas in the atmosphere demonstrated? *July 1845.*

By exposing to the air a plate or dish containing a solution of lime-water ( $\text{CaH}_2\text{O}_2$ ). After a short time the limpid liquid is covered with a thin film, which becomes thicker and thicker. If stirred, it makes the whole mass turbid. But carbonic dioxide is the only gas which produces a turbidity in lime-water.

**233.** What substances form the food of plants? *July 1847.*

Plants absorb by their roots water containing minerals, organic substances, ammonia, carbonic dioxide, and oxygen in solution. In the surface of the leaves are small openings or *stomata*, through which air containing carbonic dioxide and aqueous vapour passes. The carbonic dioxide is decomposed under the influence of sunlight by the green part of the leaves (chlorophyll), the carbon being retained and the oxygen in part returned to the air through the *stomata*. The retained carbon enters into new combinations, constituting the *sap*, which eventually is elaborated into wood, roots, leaves, flowers, and fruit.

As in animals, there is always oxidation going on in all parts of the plant, with formation of carbonic dioxide and aqueous vapour, which pass out of the plant

chiefly through the stomata. The action may be compared to the breathing of animals.

**234.** What changes take place upon the air inspired by animals? *July 1849.*

Explain how the composition of the atmosphere is affected by animal life. *Jan. 1874.*

During the life of all animals their blood is being continually charged with carbonic dioxide, resulting from the oxidation of the carbon in all the tissues. This blood (venous), on entering the lungs, is there exposed for a short time to the action of the air, being separated therefrom by a thin moist membrane; then a portion of the carbonic dioxide leaves the blood and passes into the air, while a portion of the oxygen of the air takes its place. During the act of *expiration* the air, deprived of a part of its oxygen and contaminated with carbonic dioxide and water vapour, is driven from the lungs into the atmosphere, and on *inspiration* a fresh quantity of air enters the lungs, and undergoes the same change.

**235.** Our atmosphere is said to take part in the process of combustion, of respiration, and of the growth and decay of plants. Explain how, and by means of which of its constituents, the air acts in each of these processes. *Jan. 1872.*

*In the process of combustion* the air yields its oxygen to combine with the carbon of the burning substance, forming either carbonic oxide (CO) or carbonic dioxide (CO<sub>2</sub>), and with the hydrogen forming vapour of water.

*In the process of respiration* the oxygen of the air decarbonises the venous blood, which is conveyed by

means of the red corpuscles to the lungs, which present to the action of the air the greatest possible surface. The result of the decarbonisation is the formation of carbonic dioxide, which is expelled by means of the alternate expansion and contraction of the chest and the lungs.

*In the process of growth of plants* the plants under the action of sunlight decompose the carbonic dioxide of the atmosphere, setting free at least some of its oxygen. The rest is assimilated by the plant to feed its own structure. During the night—that is to say, in the absence of light—this action does not take place. On the contrary, the plants and trees then give off carbonic dioxide, the result of their own breathing.

*In the process of the decay of plants* the oxygen of the air in the presence of moisture and heat combines with the carbon and other constituents of the plants to form carbonic dioxide and water.

**236.** How would you distinguish carbonic acid from nitrogen? *June 1865.*

*First.* I should pour into both jars containing the gases a few drops of lime-water. After having shaken the liquid, that jar in which the lime-water becomes turbid or milky is that containing the carbonic dioxide, while that in which the lime-water remains unaltered is the jar containing the nitrogen.

*Secondly.* I should lower into each vessel a lighted taper. It would be extinguished in both; but in the jar containing the carbonic dioxide the wick would be quite black, whilst in the other the wick would continue to glow for some time.

*Thirdly.* After having inverted the jars in the pneumatic trough, I should pass into each a stick of

**caustic potash** ( $K_2O$ ). This would produce no change in the jar containing the nitrogen, but in that containing the carbonic dioxide the gas would be absorbed, and consequently the water would rise.

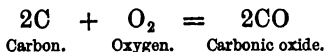
**237.** Describe briefly the mode of liquefaction of carbonic acid. *July 1847.*

The usual method of liquefying it is by putting into a very strong iron vessel a carbonate with a liquid which will decompose it and set the carbonic dioxide free. In this state carbonic dioxide occupies a very much larger space than it did when in combination. Thus, if a quantity of carbonate and acid be placed in the iron vessel sufficient to generate about 36 times its volume of gas, the pressure of the gas against the sides of the iron vessel will be so great that the gas will become liquid.

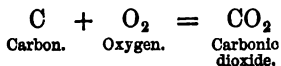
Carbonic dioxide may also be liquefied by pumping it into a strong iron receiver until about 36 volumes of gas have been compressed into the space of one. At this point it will begin to liquefy.

**238.** What compounds are formed by the combustion of carbon in a limited and in an excessive quantity of air, and what are their respective formulæ? *July 1863—June 1870.*

In a limited quantity of air carbonic oxide is formed. Its formula is  $CO$ .

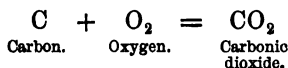


In an excessive quantity of air carbonic dioxide is formed. Its formula is  $CO_2$ .



**239.** What volume of oxygen is needed for the complete combustion of one gramme of carbon? Sixteen grammes of oxygen measure 11·2 litres. *Jan.* 1867.

From the equation of the reaction :—



it is seen that 2 atoms or  $2 \times 11\cdot2 = 22\cdot4$  litres of oxygen are wanted for the complete combustion of 12 grammes of carbon. Therefore for 1 gr. of carbon there will be wanted  $\frac{22\cdot4}{12} = 1\cdot87$  litre of oxygen.

**240.** The gas which accumulates in the Grotto del Cane, near Naples, is said to be carbonic acid. Describe how you would test by experiments the correctness of the assertion. *June* 1878—*Jan.* 1875.

The carbonic dioxide that escapes from the fissures of the Grotto del Cane, near Naples, is of a natural origin. Its density causes it for many yards to rise not above 2 feet from the ground. Consequently, as the respiratory organs of man are far above that height, one can walk with impunity through this stream of gas. But a small animal, such as a dog, soon shows signs of uneasiness, and dies if not removed. I could also test the presence of carbonic dioxide by a lighted candle, which when placed in the stream of gas goes out.

**241.** How would you test whether the air in a well consists of ordinary air or of carbonic acid? *Jan.* 1868.

I should lower into the well a lighted candle. If the candle goes out it is a sure sign that there is an accumulation of carbonic dioxide, and consequently that

the air is unfit for the support of life. Also I should lower into it a vessel containing **lime-water**. If this becomes covered with a thin film, which being stirred makes the lime-water turbid, it evidently shows that the well contains carbonic dioxide. The same thing, it is true, would happen when exposed to the ordinary atmosphere, but very much slower.

**242.** By what means would you detect carbonic acid in spring water? *Jan. 1868.*

By boiling the water and then passing the resulting gas into **lime-water**. If the lime-water becomes turbid the spring water contains carbonic dioxide.

**243.\*** How do you explain the formation of stalactites and stalagmites, which are seen in many caverns?

Rain water contains a great proportion of carbonic dioxide in solution. This water percolating through beds of calcic carbonate, takes it up freely, until, making its way through the roof of the cavern, its carbonic dioxide gradually escapes, causing the carbonate to be deposited in masses like icicles, which are called *stalactites*. A portion of the dripping water, having not yet entirely parted with all its excess of carbonic dioxide and carbonate, falls on the floor of the cavern and there causes the formation of other icicles, but in this case with their points upward. These are called *stalagmites*, and in course of time they may meet the point of the stalactite.

**244.\*** How may carbonic dioxide be proved to contain carbon?

A small piece of potassium, heated until it begins

to burn in the air, is introduced by means of a platinum spoon into a jar of carbonic dioxide: the potassium continues to burn with great brilliancy. Potassic oxide will be formed at the expense of the oxygen which the gas contains, whilst carbon will be liberated, as may be seen in the **black particles suspended in the water** in which the spoon is plunged after the combustion is complete.

But a more practical method is that of lowering into the jar containing the carbonic dioxide gas a piece of **magnesium wire previously ignited**. The heat of the magnesium decomposing the gas, the metal combines with the oxygen to form magnesian oxide (magnesia), which is deposited on the walls of the jar as a white powder, and the carbon is set free and shows itself in black spots on various parts of the jar.

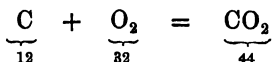
**245.** A small box, containing a live guinea pig, is placed in the pan of a delicate balance, and the instrument then exactly equipoised. If the whole be now allowed to remain at rest, it will soon be seen that a **distinct diminution of the weight of the box and its contents** occurs. Explain this fact. *June 1877.*

A diminution of weight occurs for two reasons. The first is that in the act of breathing an exchange takes place between the oxygen of the atmosphere and the carbonic dioxide. But carbonic dioxide is heavier than oxygen; hence a loss, and therefore a diminution of weight. A second reason is that through the pores of the skin of the animal, together with its breath, a considerable quantity of vapour of water is given off.

**246.** What weight of carbon is needed for the formation of 88 gr. of carbonic acid? What is the

volume of this weight of acid at 0° Centigrade and 30 inches barometric pressure? *Jan.* 1868.

The above reaction is represented by the following equation :—



44 gr. of CO<sub>2</sub> are set free by 12 gr. of C

1        „        is        „         $\frac{12}{44}$         „

∴ 88        „        are        „         $\frac{12 \times 88}{44}$

= 24 grammes of carbon.

The specific gravity of carbonic dioxide at 0° C. and 30 inches barometric pressure is 22. Consequently, to find the answer we have to reason thus :—

22 gr. of CO<sub>2</sub> occupy a volume of 11·2 litres

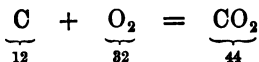
1        „        occupies        „         $\frac{11\cdot2}{22}$  litre

∴ 88        „        occupy        „         $\frac{11\cdot2 \times 88}{22}$

= 44·8 litres.

**247.** Six grains of carbon and 22 grains of oxygen are heated to redness in a hermetically closed tube. What substance, and what amount of it, is produced? *Jan.* 1879.

The equation



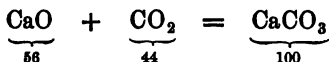
represents the reaction.

If 12 grains of carbon produce 44 of CO<sub>2</sub>, 6 grains of carbon will produce **22 grains of carbonic dioxide.**

But if 6 grains of carbon be used, only .16 of oxygen will enter into combination, and the remaining 6 grains of oxygen will remain uncombined.

**248.** How many grains of carbonic acid ( $\text{CO}_2$ ) will combine with 100 grains of calcic oxide ( $\text{CaO}$ ) to form calcic carbonate ( $\text{CaO.CO}_2$ )? [ $\text{C} = 12$ ;  $\text{O} = 16$ ;  $\text{Ca} = 40.$ ] *Jan.* 1881.

The equation of the reaction is:—



56 grains of  $\text{CaO}$  combine with 44 grains of  $\text{CO}_2$

1 grain   ,,   combines with  $\frac{44}{56}$  grain   ,,

100 grains   ,,   combine with  $\frac{44 \times 100}{56}$

= 78.57 grains.



## CHAPTER XII.

COMBUSTION—FLAME—FUEL

AND

COAL GAS.



## COMBUSTION.

**249.** What becomes of a body when burned?  
*July 1844.*

When a body has been burned, all its constituents are still in existence, but they have assumed a different form from that which they had previously. The *hydrogen* and the *carbon* have combined with the oxygen of the air to form water and carbonic dioxide respectively; the *nitrogen* is evolved free; and the *oxygen* which was present remains combined in the water and in the carbonic dioxide. The residue, if any, is called *ashes*. These consist chiefly of compounds like potassic carbonate, which cannot be reduced to gases.

**250.** How does air act on a burning substance?  
*June 1874.*

Air acts as one of the causes of combustion. The *oxygen* of the air causes the burning substance to break up into its elements by combining with those elements, such as hydrogen and carbon, which are capable of forming oxygenated compounds (*e.g.*  $\text{OH}_2$ ,  $\text{CO}_2$ ,  $\text{CO}$ ). This takes place with evolution of light and heat. The *nitrogen* of the air undergoes no change; it only moderates the rapidity of the combustion.

**251.** State the principal chemical changes which

occur during the combustion of a wax candle. *July 1844—July 1859—July 1860.*

The hydrogen combines with the oxygen of the air to form **steam**, and the carbon combines with the oxygen to form **carbonic dioxide**.

**252.** Describe the products of combustion when spirits of wine are burned in a lamp, or when a wax candle is ignited. *Jan. 1860.*

The products of the combustion of a wax candle, or of that of spirits of wine, are **steam**, arising from the combination of the oxygen of the air with the hydrogen of the compounds of the candle or of the spirits of wine, and **carbonic dioxide** arising from the combination of the carbon of the combustible with the oxygen of the air.

**253.** Explain why a candle cannot long continue to burn in a closed bottle. *Jan. 1866—June 1881.*

A candle cannot long continue to burn in a closed bottle, because, as it is shut off from the outward air, only a **limited supply of oxygen** is provided for the combustion of the carbon and the hydrogen given off by the wick. As soon, therefore, as the oxygen of the bottle has been used up, all further combinations cease, and the flame must go out.

**254.** What are the products of the combustion of metals, of hydrogen, and of ordinary fuel in atmospheric air? *July 1846—July 1850—July 1853.*

The result of the combustion in air

of metals is **oxides**,

of hydrogen is **water**,

of ordinary fuel is **water, carbonic oxide, and carbonic dioxide**.

## FLAME.

**255.** Give a sketch of the different parts of the flame of a candle ; give the names of these parts, and say in few words what takes place in each. *July 1852.*



- (a) The **dark** cone, or the area of **no** combustion.
- (b) The **luminous** cone, or the area of **incomplete** combustion, or the so-called **reducing** flame of the blowpipe.
- (c) The **non-luminous** cone, or the area of **complete** combustion, or the so-called **oxidising** flame of the blowpipe.

**256. Describe the structure of the flame of a common candle.** *July 1859—Jan. 1867—June 1871.*

Three parts can be distinguished in the flame of a candle—( $\alpha$ ) a dark part in the interior, ( $\beta$ ) a luminous cone around  $\alpha$ , and ( $\gamma$ ) a thin, almost non-luminous envelope around  $\beta$ .

**Explain the structure of the flame, and describe how you would support your explanation by experiments.** *June 1879.*

A flame is composed of three distinct parts.

( $\alpha$ ) *A dark part in the interior.* This is the part in which no combustion takes place. Its darkness is only apparent on account of the contrast between it and the luminous cone which surrounds it. It consists of transparent and invisible compounds of carbon and hydrogen, which are constantly arising in vapours from the wick. *To prove this* I need but hold obliquely in the dark cone of the flame a tube open at both ends; the gas that issues from the upper end may be kindled. ( $\beta$ ) *A luminous cone around the dark cone.* In this part it is that the gases evolved by the wick are partially burned through the agency of the oxygen of the air, a portion of which penetrates into it. The combinations take place and the solid particles of carbon become incandescent, thereby giving much light. The reason why the carbon is not burned is that the oxygen, having a greater affinity for hydrogen than it has for carbon, combines rather with the first than with the second, thus forming steam. *To prove this statement* I should hold a blade of a knife in that part of the flame. After a short time it is covered with a fine black powder, which I recognise to be lampblack. ( $\gamma$ ) *A thin non-luminous cone around  $\beta$ .* In this part the carbon, which was in a state of incandescence, coming into contact with more air, combines to

form carbonic dioxide. The heat of combination is very great, which accounts for this part being the hottest part of the flame. At the same time scarcely any particles of carbon pass uncombined, which accounts for this cone being less luminous than the previous one. *To prove that this cone is the hottest part of the flame, if I hold in it some glass this latter soon becomes soft, whilst it would remain hard if it were held in the second cone.*

**257.** Why is the light given out by a flame diminished when a current of air is blown into it? *Jan. 1867—June 1873.*

If you blow a current of air into the flame of an ordinary candle, the flame appears less bright than it did before the introduction of the air. Explain why this is the case. *June 1878.*

On blowing a moderate quantity of air into the flame, the gases arising from the combustible become more thoroughly mixed with it, and consequently complete combustion takes place more rapidly, with production of rare gases only, which, though intensely heated, give out but little heat.

If the quantity of air blown into the flame of the candle should be *too considerable*, then the wick is so much cooled that the flame goes out.

**258.** Why does the flame of an ordinary moderator lamp appear brighter with than without a chimney glass? *June 1873.*

**259.** If you place the glass cylinder over the flame of a reading lamp the flame increases in brightness. Why does it so? *June 1878.*

The effect of the glass chimney is to confine a portion of air and other gases closer to the flame, which

therefore becomes more heated, and so induces a greater current of air to play immediately upon the flame. This increases the combustion, so that more of the combustible is burned without the production of smoke. Also the gases are heated more intensely, and consequently more light is given out. The dark cone and the non-luminous one are much reduced; that of incomplete combustion, but of intense light, alone remains. That the combustion is incomplete may be proved by holding over the glass cylinder a cold plate, which is at once covered with soot.

**260.** Explain why carbon is set free by the combustion in the interior but not on the surface of the flame. *June 1871.*

The limited quantity of oxygen of the air, coming in contact with the hydrogen and the carbon supplied by the combustible matter, combines more readily with the hydrogen than with the carbon. The result of the combination is steam, accompanied at the same time with the evolution of great heat. But the heat renders the carbon incandescent; that is to say, it causes it to give out a bright light, acting as the lime does in the oxyhydrogen light. After this it is set free, and may be gathered on any cold surface held over the flame.

When some of the incandescent carbon comes nearer the surface, it comes in contact with a greater supply of oxygen. The result is that the carbon is oxidised to carbonic dioxide, producing great heat but no light, and scarcely any carbon is set free.

**261.** Explain fully why the flame of a common gas-light is brighter than the flame from a Bunsen burner. *Jan. 1866.*

Because in a Bunsen burner the air is allowed to mix itself thoroughly with the gas before combustion, by means of small holes pierced through the bottom of the tube of the burner. When a light is applied to this mixture the combustion is almost complete; *and this accounts for the absence of the luminous cone.* On the contrary, with the flame of a common gas-light the air mixes with the gas only by degrees, which circumstance causes the existence of a black cone or area of no combustion, and a luminous cone or area of partial combustion, in which the solid particles of carbon are in a high state of incandescence; *and this accounts for the flame being very bright.*

## FUEL.

**262.** What are the constituents of ordinary fuel and the products of its combustion? *July 1848—July 1850—July 1854.*

**Explain the nature of ordinary fuel.** *July 1858.*

Coal, the ordinary fuel, is a vegetable matter which has undergone, through pressure and heat, considerable changes, losing a great portion of its hydrogen and its oxygen. The constituents of coal are carbon, hydrogen, and small quantities of oxygen and nitrogen, and the products of its combustion are carbonic oxide, carbonic dioxide, and steam.

**263.** What is the difference between coal and coke? What are the principal gaseous compounds formed in the preparation of coke? *July 1862.*

Coke is coal from which all the gases have been expelled by the process of distillation in a closed retort.

It also differs from coal in physical appearance. It is hard, shining, and very porous.

The principal gaseous compounds formed in the preparation of coke are **hydrogen, marsh gas, olefant gas, carbonic oxide, carbonic dioxide, and hydric sulphide.**

**264.** Name and describe two or three of the chief varieties of coal. *July 1862.*

*Firstly.* **Cannel coal**, which word is a corruption for the word candle. This coal was so called on account of the facility with which it burns, and on account of the brightness of its flame, which is due to the quantity of gaseous matter it contains. This coal does not soil the fingers. It is the best coal that can be used for the purpose of making coal gas, and is obtained chiefly from the Northern counties.

*Secondly.* **Anthracite** is a kind of coal containing scarcely any gases, but is nearly entirely composed of carbon. It cannot, therefore, be used for the manufacture of coal gas. It is extracted from the coal mines of South Wales.

*Thirdly.* **The ordinary bituminous coal**, which in properties and in composition is between the two above-named kinds.

**265.** A current of pure air passes throught a bright coke fire. **What gases are contained in the air beyond the fire?** Give a short description of each of them. *June 1868.*

The gases that pass through a bright coke fire are **carbonic oxide and carbonic dioxide.** The quantity of the carbonic oxide varies greatly with the intensity and the size of the fire. This gas results from the combina-

tion of carbon with oxygen present in a limited quantity, and from the decomposition of the carbonic dioxide by the action of heat. The carbonic dioxide results from the combination of carbon with oxygen when the latter is in excess, and also from the combustion of carbonic oxide.

Carbonic dioxide is a colourless and invisible gas, with a somewhat pungent smell. It is not combustible, nor does it support combustion or life. Carbonic oxide is also a colourless and invisible gas with a slight oppressive smell and no taste. It does not support combustion, but burns with a bright blue flame, producing carbonic dioxide. It is exceedingly poisonous.

**266.** What is the process which takes place at the lower part of a charcoal fire through which moist air ascends? What changes do the resulting gases undergo on passing through the upper portion of the fire? *Jan.* 1864.

When moist air is made to pass through a charcoal fire, carbonic dioxide is first formed, because oxygen is in excess; but as the carbonic dioxide and the steam pass upwards they reach a point where carbon is in excess, and then the carbonic dioxide becomes reduced to carbonic oxide, and the steam to hydrogen. Then again, the carbonic oxide by means of more oxygen is oxidised again to carbonic dioxide, and so on. The carbonic oxide that reaches the surface burns there in contact with air, with a bright blue flame, forming again a new quantity of carbonic dioxide, which escapes together with the other undecomposed gases.

**267.** What are the component parts of gunpowder and the sources of its explosive power? In what points is gun-cotton analogous to gunpowder? *July* 1847.

The component parts of gunpowder are sulphur, charcoal, and saltpetre. The source of its explosive power is the sudden expansion of the gases produced by the combinations these substances form among themselves.

Gun-cotton is analogous to gunpowder chiefly because it contains in itself, in every part of the mass, the oxygen necessary for complete combustion. The combustion, therefore, is almost instantaneous, and therefore explosive.

## COAL GAS.

**268.** What are the combustible elements of coal gas? *July 1845.*

The combustible elements of coal gas are hydrogen, marsh gas, olefiant gas, carbonic oxide, and hydric sulphide.

**269.** How is coal gas manufactured? *July 1845—July 1853.*

The coal is introduced into clay or iron retorts and strongly heated by a coke fire. After a short time the coal gas issues from the retorts and is received into purifiers. It is first made to pass through a series of iron siphons, kept cool, in which the tar and the ammoniacal liquor are deposited. Then the gas is made to traverse vessels containing slaked lime, by which the useless carbonic dioxide and the noxious hydric sulphide are retained. Finally, the gas is collected in large metallic reservoirs called gasometers, from which it is conducted to the consumer by means of pipes for heating, cooking, or lighting purposes.

**270.** What are the products of the combustion of coal gas, and why does it burn after a large quantity of air is mixed with it, with little or no light? *July 1845—June 1866—June 1873.*

The products of the combustion of the coal gas are water and carbonic dioxide, with traces of sulphurous dioxide. The reason why it burns with scarcely any light when a large quantity of air is mixed with it is because the carbon and the hydrogen are both burned simultaneously, producing no light but an enormous quantity of heat. This property has been taken advantage of in the construction of Bunsen burners.



## CHAPTER XIII.

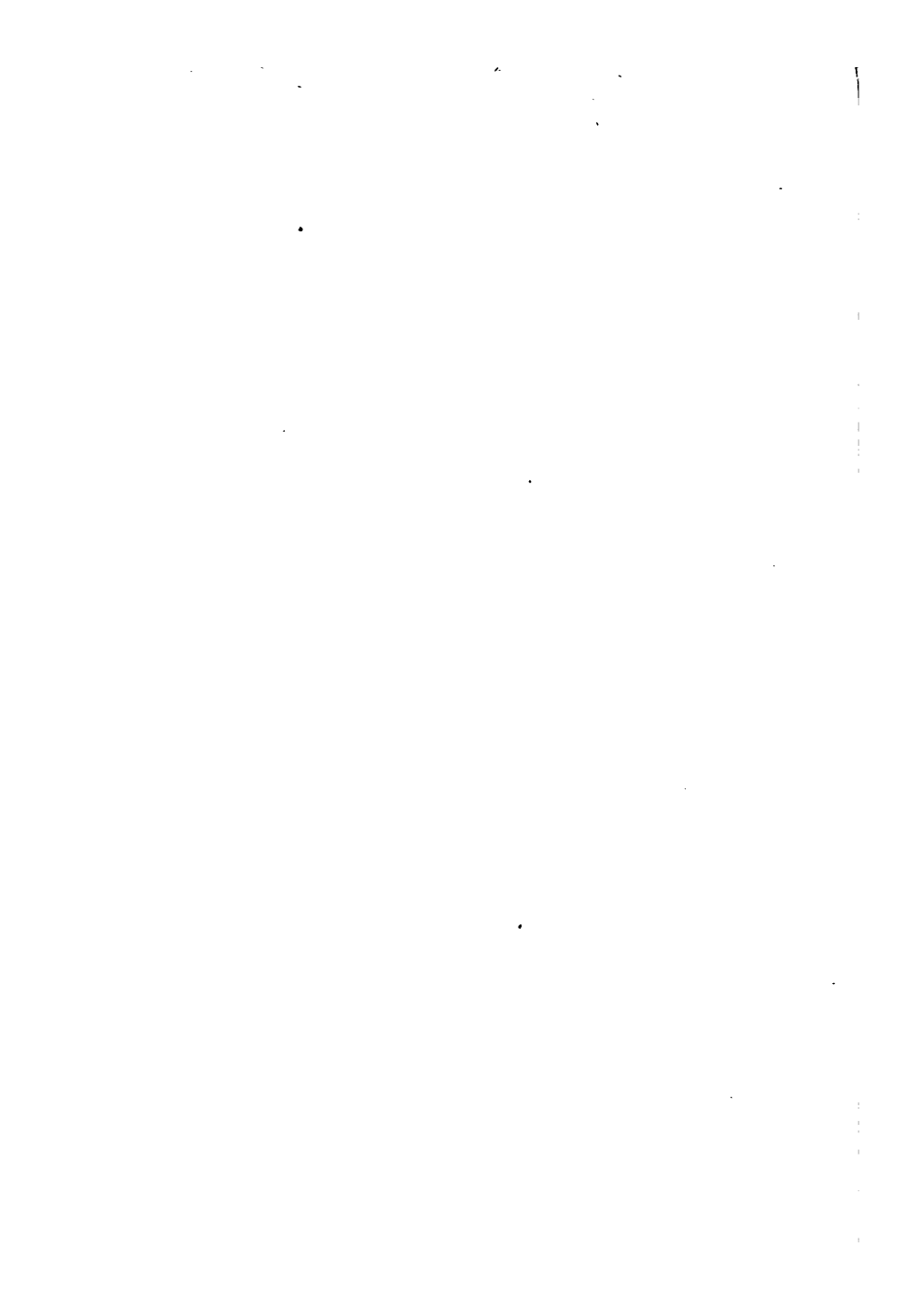
### CHLORINE (Cl).

(Monad, as in HCl.)

$$\frac{(\text{Cl}_2) \text{ Molecular weight, } 71.}{\text{Molecular volume, } \boxed{\begin{array}{|c|} \hline 1 \\ \hline \end{array}}} = 35.5 \text{ sp. gr.}$$

Or 35.5 grammes of Cl measure 11.2 litres.

35.5 grains of Cl measure 44.4 cubic inches.



## CHLORINE.

**271.** Into what remarkable compounds does chlorine enter as an element? *July 1846—July 1853.*

Chlorine enters as an element into the remarkable and numerous class of chlorides or metallic chlorides; e.g.  $\text{HCl}$ ,  $\text{KCl}$ ,  $\text{NaCl}$ ,  $\text{AgCl}$ , &c.

**272.** Why can chlorine not exist free in nature? *June 1872.*

Because gases of organic origin, of which hydrogen is a constituent, are always present in the atmosphere; and as chlorine readily forms a chemical combination with hydrogen, those gases would be decomposed and the chlorine would combine with the hydrogen to form hydric chloride.

**273.** How is chlorine gas prepared? *July 1846—July 1849—July 1850—July 1853—July 1858—Jan. 1861—Jan. 1864—Jan. 1866—Jan. 1868.*

How do you prepare chlorine? and how do you explain your process? *June 1872.*

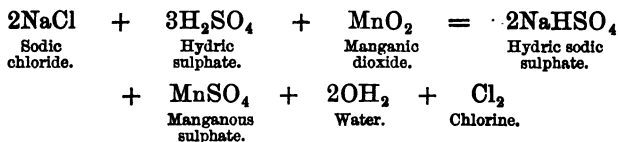
Chlorine is most conveniently prepared by heating in a flask a mixture of manganic dioxide ( $\text{MnO}_2$ ) and strong hydric chloride ( $\text{HCl}$ ). The manganic dioxide being a very strong oxidising agent (i.e. ready to yield its oxygen to another element for which it has a greater

attraction for combination), combines with the hydrogen of the hydric chloride, forming water, at the same time setting free the chlorine. This reaction is expressed by the following equation :—



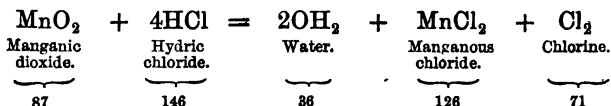
**274.** Express in symbols what takes place when sulphuric acid, chloride of sodium, and oxide of manganese are heated together. *June 1870.*

A double reaction takes place. First there is the formation of hydric chloride (HCl) by the action of sodic chloride (NaCl) (common salt) on hydric sulphate ( $\text{H}_2\text{SO}_4$ ) (oil of vitriol), then the formation of free chlorine by the action of the manganic dioxide on the hydric chloride already obtained. The complete reaction is expressed by the following equation :—



**275.** Express in symbols the reaction which occurs when hydrochloric acid is heated with black oxide of manganese. Give the relative proportions by weight of the elements described by your symbols. *Jan. 1863—June 1873.*

The reaction is expressed by :—



It must be remembered that the numbers 87, 146, 36, &c., are relative weights, and so may stand for grammes, grains, pounds, or tons; also that the test of correctness of an equation is that the number of atoms of the elements on one side should be equal to the number of atoms of the elements on the other. So  $87 + 146 = 36 + 126 + 71$ ; or  $233 = 233$ .

**276.** Describe the **properties of chlorine gas.** *July 1845—July 1849—July 1850—Jan. 1861—Jan. 1863—Jan. 1864—Jan. 1868.*

**277.** Describe the **physical properties of chlorine gas.** *July 1845.*

*Physical Properties.*—Chlorine is a gas of a **yellowish green colour**, having a disagreeable and suffocating smell, which it is even dangerous to inhale in large quantities, as it produces inflammation of the mucous membrane. Its specific gravity is 2.44; that is to say, 1 litre of that gas weighs, compared to air,  $2.44 \times 1.293 = 3.16$  grammes. At the ordinary temperature water **dissolves about twice its volume**. When this solution is exposed to the light it is slowly changed, in consequence of the chlorine decomposing the water. It is for this reason that chlorine water is kept in the dark or in dark-coloured bottles. When **exposed to a cold of  $0^{\circ}$**  this solution **yields yellow crystals**. Chlorine gas liquefies when at  $15^{\circ}$  C. under the pressure of 4 atmospheres.

*Chemical Properties.*—Chlorine is **not combustible**. A taper burns in it with a reddish smoky flame. It forms with oxygen compounds which decompose into their elements under the least provocation. But, on the contrary, the compounds chlorine forms with hydrogen and metals are most stable and most energetic. With

some gases this combination takes place with flame; and with hydrogen it combines, under suitable circumstances, with explosion. Many bodies, such as phosphorus, or finely divided copper, antimony, or arsenicum, take fire spontaneously when introduced into chlorine. The attraction of chlorine for hydrogen is such that it causes the decomposition of organic substances rich with it. Thus a bit of paper dipped into oil of turpentine and plunged into chlorine gas bursts into flame. As most vegetable colouring matters and noxious vapours contain hydrogen, chlorine is used as a bleaching agent and a disinfectant.

**278.** What happens when a mixture of one volume of chlorine and two volumes of hydrogen is exposed to the sun's light? How will water act on the product of the reaction? *June 1873.*

As chlorine and hydrogen combine in equal volumes, and not in any other proportion, a body corresponding to the symbol  $H_2Cl$  does not and cannot exist. Hence 1 vol. of chlorine will combine with 1 vol. of hydrogen to form hydric chloride ( $HCl$ ), while the other volume of hydrogen will be left uncombined. This combination, taking place under the influence of the direct rays of the sun, is so sudden and violent that an explosion follows.

Water will dissolve hydric chloride with exceeding readiness, as it is capable of dissolving, when at the freezing point, about 550 times its own volume of hydric chloride.

**279.\*** Why should chlorine water be kept in the dark or in dark-coloured bottles?

Because the chlorine gas, favoured by the direct rays of sunlight, decomposes the water, combining with the

hydrogen to form hydric chloride and setting the oxygen free.

**280.** Describe the preparation and properties of liquid chlorine. *Jan.* 1864.

Pass chlorine into cold, icy water. Crystals will be formed containing chlorine with 10 molecules of water. Then place these crystals in a tube, and seal it. By gently heating these crystals they will decompose in water, which will dissolve a portion of the chlorine, and the remaining chlorine will be free liquid chlorine. This is of a deep green colour, more dense than the portion dissolved in water, which floats at the surface. The properties of the liquid chlorine are the same as those of the gas (see No. 277).

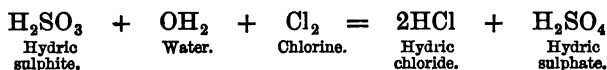
**281.** Chlorine often acts as an oxidising agent. How do you account for this? Describe some experiment in proof of your explanation. *Jan.* 1878.

By an oxidising agent is meant a body ready, under certain circumstances, to give up its oxygen, which being then in the *nascent state*, combines readily with another element. For this reason hydric nitrate ( $\text{HNO}_3$ ) is said to be an oxidising agent. Now chlorine, as it does not contain any oxygen, cannot be said to be an oxidising agent in the same sense as the above-mentioned body is; but chlorine may be called such *indirectly*, because by its action upon metallic oxides it drives out the oxygen, which oxygen, being in the *nascent state*, may then easily combine with some other body.

Thus if chlorine be made to act upon vegetable colouring matter to which a few drops of water have been added, it decomposes the water into hydrogen to form hydric chloride, setting the oxygen free. At the

moment of its liberation the oxygen combines with the vegetable colouring matter, forming compounds destitute of colour.

We have another example of the indirect oxidising action of chlorine when chlorine is made to decompose water in the presence of hydric sulphite.



A similar reaction oxidises arsenious ( $\text{As}_2\text{O}_3$ ) and phosphorous trioxides ( $\text{P}_2\text{O}_3$ ), changing them into arsenic ( $\text{As}_2\text{O}_5$ ) and phosphoric pentoxides ( $\text{P}_2\text{O}_5$ ) respectively. When chlorine decomposes water in the presence of ferrous sulphate ( $\text{FeSO}_4$ ), the liberated oxygen changes the ferrous sulphate into ferric sulphate,  $\text{Fe}_2(\text{SO}_4)_3$ . That such is the case may be easily proved. The *ferrous salts* are distinguished by their light green colour, and by their solutions giving a white precipitate with caustic alkalies (such as KHO) and a light blue precipitate with potassic ferrocyanide (KCy), which rapidly becomes dark. *Ferric salts*, on the other hand, are of a yellow colour, and their solutions yield a deep reddish brown precipitate with the caustic alkalies, and a deep blue precipitate with potassic ferrocyanide.

That water is necessary for these reactions is thus shown:—If you place a strip of dry litmus paper in a jar of dry chlorine the paper will not be bleached; but place a few drops of water in the jar, or moisten the paper, and it will be bleached almost immediately.

**282.** Explain the action of chlorine gas upon oxide of potassium, by which chlorate of potash is formed; and of chlorine upon lime, by which hypochlorite is produced. *July 1852.*

When chlorine is passed to saturation into a hot solution of potassic oxide ( $K_2O$ ), potassic chlorate ( $KClO_3$ ) is formed.



The chlorine succeeds in breaking up the potassic hydrate and in forming 1 mol. of potassic chlorate, 5 mol. of potassic chloride, and 3 mol. of water.

If the liquid be concentrated, it yields, on cooling, flat tubular crystals of a colourless salt, which is potassic chlorate.

When chlorine acts upon slaked lime ( $CaO, OH_2$  or  $CaH_2O_2$ ), a mixture of calcic hypochlorite ( $CaCl_2O_2$ ) and calcic chloride ( $CaCl_2$ ) is formed. That mixture is known under the name of **bleaching powder**. It constitutes, so to speak, a ready store of chlorine, which is set free by diluted acids, or even by one of the weakest of acids, the carbonic dioxide of the atmosphere. The reaction may be expressed thus:—

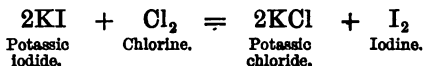


The chlorine decomposes the calcic hydrate, forming water, calcium chloride, and calcic hypochlorite.

**283.** Explain what happens when a current of chlorine is passed through a solution of potassic iodide. How would you prove a brown liquid to be an aqueous solution of iodine? *June 1872.*

As chlorine has a greater affinity for metals than iodine has, it follows that if a current of chlorine be passed through a solution of potassic iodide ( $KI$ ), the

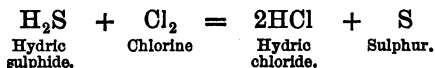
chlorine combines with the potassium (K) of the potassic iodide, **setting the iodine free.**



The most characteristic property of iodine is the production of a splendid rich blue colour by contact with starch paste. But this only takes place when the iodine is set free. Therefore, if a brown liquid be suspected of containing iodine in solution, take a few drops of it, and by the addition of some starch paste the contents of the glass will be turned blue, if iodine be present.

**284.** Explain the action of chlorine on sulphuretted hydrogen. *Jan. 1865.*

The chlorine, forming chemical compounds with more readiness with hydrogen (H) than with sulphur (S), when put in the presence of hydric sulphide ( $\text{H}_2\text{S}$ ) decomposes it into hydrogen and sulphur. With the former it combines to form hydric chloride, while the latter is left free. The equation of the reaction is:—



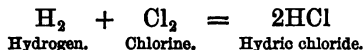
This explains why chlorine is said to be a disinfectant, and shows how it deprives gases of their *noxious* characters.

**285.** What action has chlorine gas at the ordinary temperature on the following substances:—Carbon, hydrogen, phosphorus, water, sulphuretted hydrogen, and a solution of sulphurous acid? *June 1876.*

*On Carbon.*—Chlorine has no action at all.

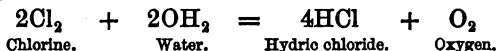
*On Hydrogen.*—At the ordinary temperature, under

the influence of the direct sunlight, **hydrogen combines with the chlorine**, forming hydric chloride (HCl). This combination takes place with such energy that an explosion occurs. The equation of the reaction is :—

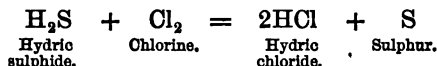


*On Phosphorus.*—Chlorine combines with it, forming two chlorides—phosphoric trichloride ( $\text{PCl}_3$ ), a liquid product which soon becomes solid if the chlorine be in excess, forming phosphoric pentachloride ( $\text{PCl}_5$ ).

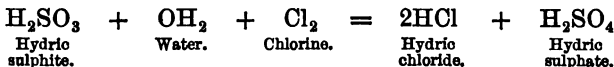
*On Water.*—Dissolved in water, under the influence of light, the **chlorine decomposes water**, forming hydric chloride and setting free the oxygen, according to the equation :—



*On Sulphuretted Hydrogen.*—Chlorine decomposes **sulphuretted hydrogen**, setting the sulphur free and forming hydric chloride, according to the equation :—



*On a Solution of Sulphurous Acid.*—Chlorine, acting upon water, causes the oxygen of the water to oxidise the sulphurous acid or hydric sulphite, changing it into hydric sulphate :—



**286.** Chlorine will bleach vegetable colours. How is this action of chlorine usually explained? *Jan. 1882.*

Most of the **vegetable colouring matters** contain hydrogen which are decomposed by chlorine, the chlorine combining with the hydrogen to form hydric

chloride. These colourless or nearly colourless compounds containing chlorine are formed in the place of the coloured compounds with hydrogen. When a vegetable colouring matter is bleached by chlorine it can never be restored; not so if bleached by sulphurous dioxide.

**287.** Four bottles, containing oxygen, hydrogen, nitrogen, and chlorine respectively, are given to you, with the request to **determine the nature of the gas** in each bottle. How would you distinguish each of these gases from the others? *June 1865.*

The bottle containing *the chlorine* is sufficiently marked off from the others by its **yellowish green colour**. Moreover a **lighted taper will burn** in chlorine with a heavy blackish smoke. In the bottle containing *the nitrogen* it will simply be **extinguished**. In that containing *the hydrogen* the lighted taper is **extinguished** at the same time as it causes the **gas to burn**, while in that containing *the oxygen* it will continue to **burn with greater brilliancy**.

**288.** Describe the effects produced by chlorine on the following substances: indigo solution, copper foil, powdered antimony, powdered charcoal, phosphorus, and sulphur. *June 1867.*

Chlorine on indigo solution **discolours it**.

Chlorine on copper foil **combines**, forming cupric chloride ( $\text{CuCl}_2$ ).

Chlorine on powdered antimony **causes it to burn**, giving off antimonious chloride ( $\text{SbAs}$ ), antimonie chloride ( $\text{SbCl}_5$ ).

Chlorine on powdered charcoal **has no action**.

Chlorine on phosphorus **burns**, forming phosphorous chloride ( $\text{PCl}_3$ ) or phosphoric chloride ( $\text{PCl}_5$ ).

Chlorine on sulphur reacts, forming a sulphurous chloride ( $\text{Cl}_2\text{S}_2$ ) or sulphuric chloride ( $\text{Cl}_2\text{S}$ ).

**289.** If one bottle contained chlorine gas, and another bromine vapour, how could you distinguish the two substances from each other? *Jan. 1872.*

*Firstly.* I could distinguish them by their colour, chlorine being of a yellowish green colour and bromine of a brownish red colour.

*Secondly.* By their smell, which is very characteristic. If once smelt, they could not be mistaken for one another. Chlorine has a strong, suffocating odour, and bromine a strong, pungent smell resembling that of decayed seaweed.

*Thirdly.* Chlorine and bromine both combine with hydrogen to form hydrides, but in the case of chlorine, if exposed to the direct rays of the sun, it combines with explosion, which is not so in the case of bromine.

*Fourthly.* Paper dipped in starch paste is not coloured by chlorine, but is turned into a yellowish green by bromine.

**290.** A gas is found by analysis to consist of equal volumes of chlorine and hydrogen. Describe fully how you would find by experiment whether the gas is a mechanical mixture or a chemical combination of the two elements. *Jan. 1875.*

If these two gases exist in a state of mixture, the greenness of the chlorine may still be detected. On presenting a lighted taper, the mixture will combine with explosion, forming hydric chloride, which dissolved in water will turn blue litmus paper red. If the gas be a chemical combination of chlorine and hydrogen it will not be affected by the flame.

Then if the gas be a compound the whole will be readily soluble in water; if merely a mixture, only the chlorine will be soluble in water. Hence, after having shaken it up with water, the hydrogen will remain, and on application of a light burn with a pale flame.

**291.** Describe the relation in which chlorine stands to hydrogen and metals. *July 1845.*

Chlorine stands in the relation of a powerful agent to enter into ready combination with hydrogen and the metals, forming a class of bodies called chlorides. The chloride formed with hydrogen is called 'hydric' chloride, and those formed with the metals are called 'metallic' chlorides.

**292.** Mention the elements which are allied to chlorine. *Jan. 1861.*

The elements that are allied to chlorine are bromine, iodine, and fluorine. All four are monads, combine readily with hydrogen to form the following hydrides:  $\text{HCl}$ ,  $\text{HBr}$ ,  $\text{HI}$ ,  $\text{HFl}$ . This readiness of combination with hydrogen goes on decreasing from the chlorine to the fluorine. With oxygen, on the other hand, their readiness of combination is in the inverse ratio to that of hydrogen. With a metallic element the members of this group form a class of salts which are called '*halogen salts*.'

**293.** State the useful application of chlorine in the arts. *July 1845.*

Describe the purposes to which chlorine is applied. *July 1858.*

Chlorine is applied chiefly for two purposes. *Firstly*, for the purpose of decomposing the colours of organic

origin, such as indigo. It is largely used also in the arts for bleaching linen and cotton goods, rags for the manufacture of paper, &c. *Secondly*, chlorine is one of the best and most potent substances that can be used for disinfecting. It is usually stored up in the substance known in commerce by the name of bleaching powder ( $\text{CaCl}_2\text{O}_2$ ), from which it may be expelled by the weakest acids.



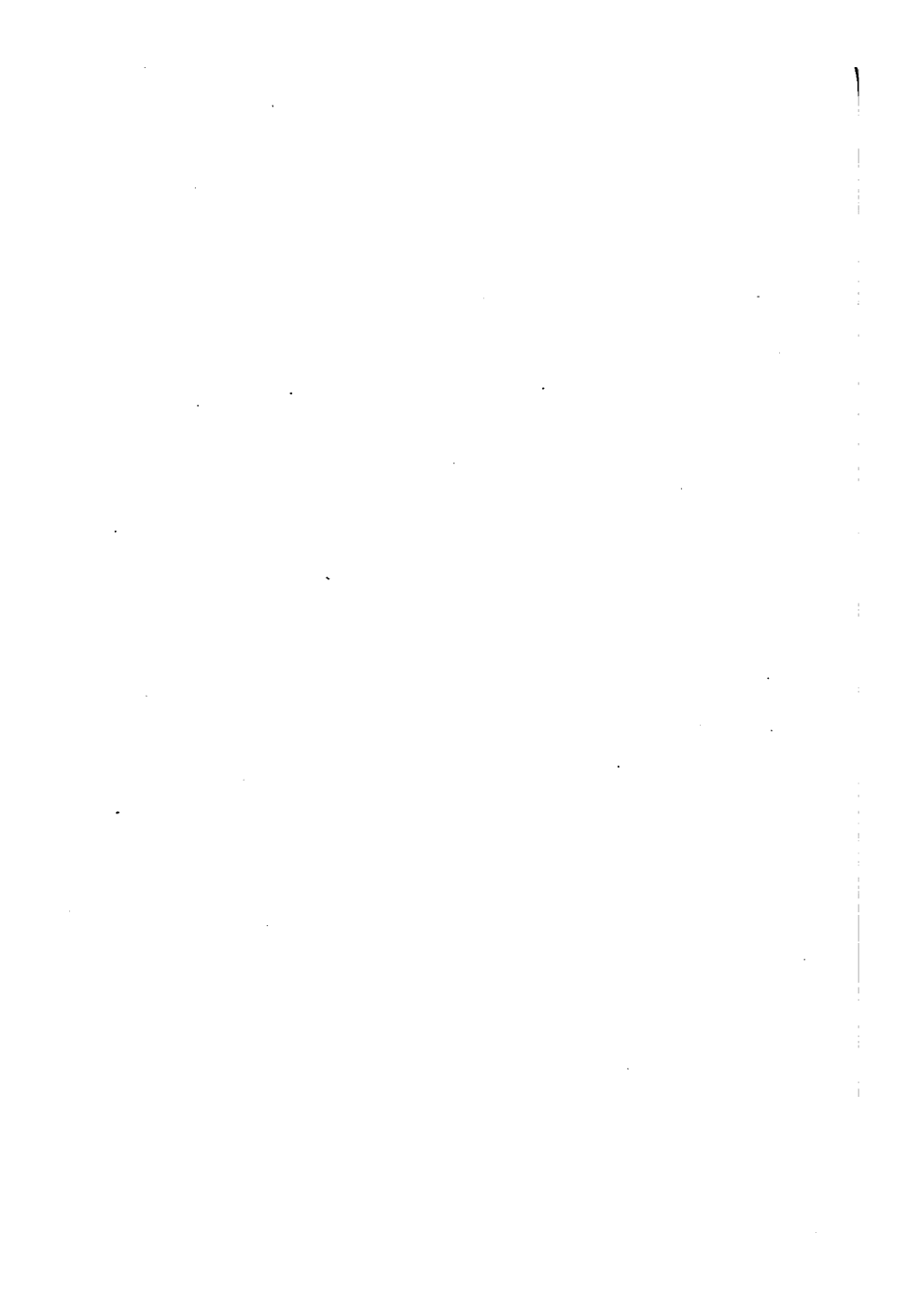
## CHAPTER XIV.

### HYDRIC CHLORIDE (HCl).

(Hydrochloric Acid—Muriatic Acid—Spirits of Salts.)

$$\frac{\text{Molecular weight, } 36.5.}{\text{Molecular volume, } \boxed{2}} = 18.25 \text{ sp. gr.}$$

Or 18.25 grammes of HCl measure 11.2 litres.  
18.25 grains of HCl measure 44.4 cubic inches.



## HYDRIC CHLORIDE.

**294.** What is the composition of hydrochloric acid by weight and by volume? *July 1849—July 1855—July 1857—Jan. 1861—July 1863—June 1864.*

**By weight** it is 1 of H and 35.5 of Cl.

**By volume** it is 1 of H and 1 of Cl.

**295.** What is the density of hydric chloride in the state of vapour? *July 1855—Jan. 1861.*

Its density compared with hydrogen is its molecular weight, 36.5, or  $(1 + 35.5)$ , divided by its volume, which is 2, and which is often represented by  $\boxed{\frac{36.5}{2}}$ .

$$\text{Thus its density} = \frac{36.5}{2} = 18.25.$$

**296.** Why is hydric chloride called by some chemists hydrochloric acid? *June 1881.*

It is called by them an acid because it turns blue litmus red, and also precipitates the metals of the bases from their solutions. It is called chloric because it contains chlorine, and hydro- because it contains hydrogen; expressing at the same time that it is an hydracid to distinguish it from an oxacid.

**297.** State the composition of nitric, sulphuric, and hydrochloric acids.

Describe the results observed when the metal copper is dissolved in the first-named of these acids, and when the metal zinc is dissolved in either of the two other acids named. *July 1851.*

The composition of nitric acid (hydric nitrate) is 1 atom of H, 1 of N, and 3 of O ( $\text{HNO}_3$ ).

The composition of sulphuric acid (hydric sulphate) is 2 atoms of H, 1 of S, 4 of O ( $\text{H}_2\text{SO}_4$ ).

The composition of hydrochloric acid (hydric chloride) is 1 atom of H and 1 of Cl ( $\text{HCl}$ ).

When copper is dissolved in hydric nitrate, red fumes are given off, and a blue liquid is formed, which crystallises by evaporation.

When zinc is dissolved in hydric sulphate, hydrogen is evolved, and a solution of zinc sulphate remains, which may also be crystallised by evaporation. Finally, when zinc is dissolved in hydric chloride, there is formation of free hydrogen, also a solution of zinc chloride remaining.

**298.** How would you distinguish aqueous hydrochloric acid from an aqueous solution of nitric acid? *Jan. 1869.*

*Firstly.* I should dip a piece of silver, or better still copper, into each liquid. Both solutions being diluted, the one containing hydric chloride would have no action upon the copper or upon the silver. On the contrary, when dipped into the bottle containing the hydric nitrate, heavy red fumes would at once be formed, and the liquid would become green or blue.

*Secondly.* I should dip the horny portion of a quill into such solution. Dipped into that containing the hydric nitrate, the quill would become yellow, but not so when dipped into that containing the hydric chloride.

*Thirdly.* I should pour a few drops of argentic nitrate into both vessels. That in which a white precipitate would be produced would be the solution of hydric chloride, and that in which no precipitate is formed would be the solution of hydric nitrate.

**299.** What are the tests of hydrochloric acid? *July 1857.*

Argentio chloride produces a white precipitate when poured into a solution of hydric chloride, and hydric chloride when poured over common salt gives off dense white fumes and great heat.

**300.** What products are obtained on mixing nitric acid with hydrochloric acid? *Jan. 1863.*

If hydric nitrate be mixed with hydric chloride in the proportion of 1 : 3, then a liquid is formed which has the property of dissolving gold, whence it obtained the name of 'aqua regia,' gold being considered the king (*rex*) of metals by the alchemists. It is generally supposed that the real solvent in this case is chlorine in the 'nascent' state, resulting from the partial combination of one acid with the other.

**301.** What volume of hydrochloric acid gas is needed in order to condense a cubic inch of ammonia? *June 1868.*

Since hydric chloride and ammonia combine in equal volumes, it is clear that one cubic inch of hydric chloride will be needed to condense one cubic inch of ammonia.

**302.** It is asserted that one molecule of hydrochloric acid consists of one atom of chlorine and one

atom of hydrogen. What do we mean by one atom of hydrogen? *Jan.* 1868.

By one atom of hydrogen we mean the smallest amount of hydrogen that can enter into combination with chlorine or with any other monad substance, in order to form one molecule of hydric chloride.

**303.** How many volumes of their respective elements are contained in two volumes of each of the following gases: hydrochloric acid, steam, and ammonia? *June* 1866.

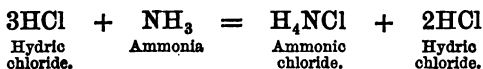
In 2 volumes of hydric chloride there are contained 1 vol. of H and 1 vol. of Cl.

In 2 volumes of steam there are contained 2 vol. of H and 1 vol. of O.

In 2 volumes of ammonia there are contained 3 vol. of H and 1 vol. of N.

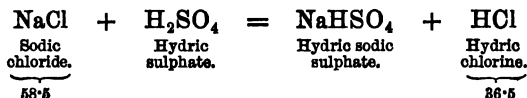
**304.** What happens when one volume of ammonia gas and three volumes of hydrochloric acid gas (hydric chloride) are mixed together? *Jan.* 1873.

When one volume of ammonia gas and three volumes of hydric chloride acid gas are mixed together, they combine at once, with formation of dense white fumes. But, as they combine in equal volumes, there will be a residue of 2 volumes of free hydric chloride.



**305.** What weight and what volume of hydrochloric acid gas (hydric chloride) could be obtained from 100 grammes of pure common salt (sodic chloride)? *Jan.* 1871.

The equation of the reaction is:—



58.5 grammes of salt yield 36.5 grammes of HCl

1 gramme „ yields  $\frac{36.5}{58.5}$  gramme „

100 grammes „ yield  $\frac{36.5 \times 100}{58.5}$

= 62.393 grammes.

$\frac{36.5}{2} = 18.25$  sp. gr. of HCl. Thus we have:—

If 18.25 grammes of HCl occupy 11.2 litres

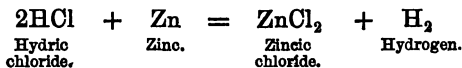
1 gramme „ occupies  $\frac{11.2}{18.25}$  litre

62.393 grammes „ occupy  $\frac{11.2 \times 62.393}{18.25}$

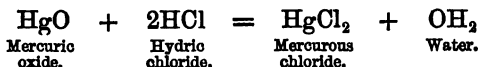
= 38.2 litres.

**306.** Explain the action of aqueous hydrochloric acid on zinc, on red oxide of mercury (mercuric oxide), and on black oxide of manganese respectively. *Jan. 1871.*

1. *Action of Hydric Chloride on Zinc.*—The hydrogen of the hydric chloride is driven out by the metal zinc, and set free. Zincic chloride remains.



2. *Action of Hydric Chloride on Mercuric Oxide.*—The hydrogen of the hydric chloride is set free by the mercuric oxide, and mercuric chloride and water are produced.



**3. Action of Hydric Chloride on Manganic Dioxide.—**

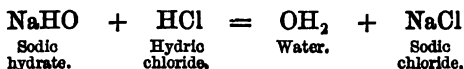
Part of the chlorine of the hydric chloride is set free, and part of it combines with the manganese of the oxide to form manganous chloride.



**307.** Explain the reactions which take place when an aqueous solution of hydrochloric acid is placed in contact with zinc, sodic hydrate, and black oxide of manganese respectively. *June 1872.*

*Reactions of Hydric Chloride upon Zinc and manganic dioxide have been explained in the preceding number.*

*Reaction of Hydric Chloride upon Sodic Hydrate.—The hydrogen of the hydric chloride is expelled to make room for the sodium of the hydrate; and the hydrogen combines with the oxygen and hydrogen of the hydrate to form water. The reaction may be expressed by the following equation:—*

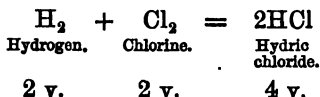


**308.** How many volumes of chlorine and hydrogen are required for the formation of 100 cubic centimetres of hydrochloric acid? *June 1872.*

For the formation of 100 c.c. of hydric chloride, as is seen from the equation given in the following number, there will be required 50 c.c. of hydrogen and 50 c.c. of chlorine.

**309.** How many volumes of chlorine and hydrogen are required for the preparation of two volumes of hydrochloric acid? *June 1867.*

Since chlorine and hydrogen combine in equal volumes to form hydric chloride, according to this:—



1 volume of chlorine and 1 volume of hydrogen will be required.

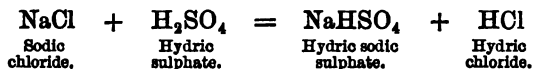
**310.** Give several reactions by which hydrochloric acid may be prepared; and how can this gas be obtained in the liquid state? *Jan. 1876.*

1. By the direct combination of hydrogen with chlorine:—

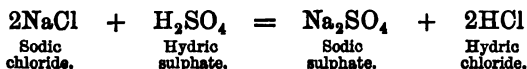


2. By the action of hydric sulphate on common salt:—

*At a low temperature—*



*At a high temperature—*



3. By allowing concentrated hydric sulphate to drop slowly on concentrated hydric chloride.

Under a pressure of 40 atmospheres at 10° C. this gas becomes condensed to a colourless liquid.

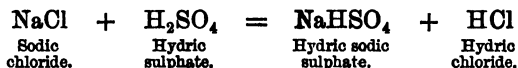
**311.** Express in symbols what takes place when sulphuric acid and chloride of sodium are heated together. *Jan. 1865—June 1870—June 1872.*

**Explain the action of oil of vitriol on common salt.**  
*Jan. 1862—Jan. 1871.*

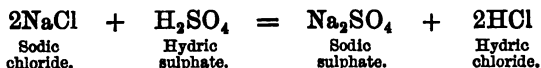
**Explain, by means of symbols, the preparation of hydrochloric acid from common salt and sulphuric acid.**  
*June 1867—Jan. 1869.*

**What happens when common salt is mixed with hydric sulphate ( $\text{H}_2\text{SO}_4$ )? Explain the reaction by means of symbols.** *June 1881.*

Having previously fused the sodic chloride, mix it with strong hydric sulphate. The evolution of gas begins before the application of heat. Afterwards heat it gently. The gas may be collected either over mercury or also by downward displacement. The reaction that takes place is very simple. The sodium of the chloride interchanges with part of the hydrogen of the hydric sulphate. This may be represented by the following equation :—



**If the production of the sodic sulphate be required at the same time, then use only half as much hydric sulphate, or, what comes to the same thing, double the amount of sodic chloride, as in the former experiment, and then hydric chloride and sodic sulphate will be produced simultaneously, on application of greater heat, as seen in the following equation :—**



**312. What are the properties of hydric chloride gas?** *July 1849—July 1850—July 1855—July 1857—Jan. 1862—July 1863—June 1864—Jan. 1876.*

**Hydric chloride is a transparent and colourless gas,**

with a very irritating and pungent smell and with a strong acid taste. It reddens dry litmus paper. It is very injurious to vegetation, causing the leaves of plants to shrivel and turn brown. It neither burns nor supports combustion. As it is heavier than air, it may be collected by downward displacement. Water dissolves nearly 480 times its volume of hydric chloride gas. Such a solution constitutes the ordinary *spirits of salts*, or the *muriatic acid* of commerce. It may be reduced to a liquid under a pressure of 40 atmospheres.

**313.** Why does dry hydric chloride ( $\text{HCl}$ ) produce a cloud when it is allowed to mix with common air? *June 1881.*

Because the air of the atmosphere, containing a certain amount of vapour of water, is condensed into a small bulk by dry hydric chloride, and so becomes visible, like the clouds in the air.

**314.** Describe an experiment to show that hydrochloric acid gas is composed of equal volumes of its constituents, united without condensation. What is the weight of 11.2 litres of this compound ( $\text{Cl} = 35.5$ )? *Jan. 1877.*

Explode a mixture of equal volumes of hydrogen and chlorine either by exposure to the sunlight or by the electric spark; the whole mixture is reduced to hydric chloride without residue either of hydrogen or of chlorine. This shows that hydric chloride contains half its volume of hydrogen and half of chlorine combined without condensation. Also decompose hydric chloride by electricity in an apparatus similar to that used for the decomposition of water. We find that equal volumes of hydrogen and of chlorine are given off from

the negative and positive pole respectively. In the first experiment I proceeded by *synthesis*, in the second by *analysis*. The weight of 11.2 litres of this compound is 18.25 grammes.

**315.** How could you prove that hydrochloric acid gas contains chlorine and hydrogen? *June 1877.*

To prove that hydric chloride contains hydrogen, I should pour it upon some metallic zinc. Some gas would be evolved, which when collected I should easily ascertain to be hydrogen by its burning with a pale flame with formation of water. To prove that it contains chlorine, I should heat it together with some manganic dioxide. After a short time a yellowish green gas would be evolved, which could easily be ascertained to be chlorine by holding over it a strip of moist litmus paper, which it would immediately discolour.

I could also prove it by the electrolysis of hydric chloride. Decompose hydric chloride in the dark by passing an electric current through it, and if the evolved gases be collected in a tube inverted over the platinum terminals, it may be shown that the gas thus obtained consists of a mixture of equal volumes of hydrogen and chlorine.

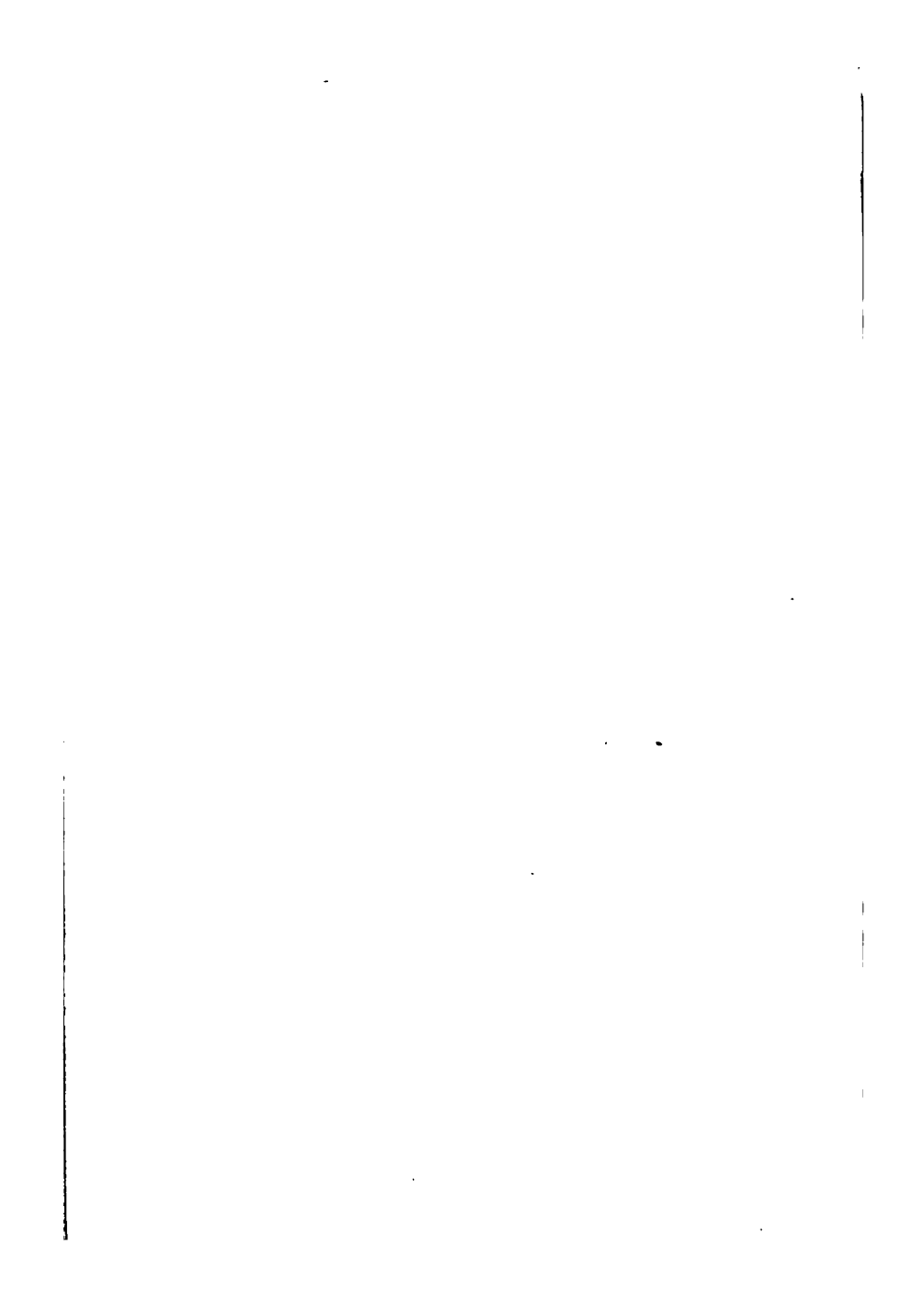
On the tube being opened under a solution of potassic iodide, the latter will be decomposed; the iodine is set free, and the chlorine takes its place, combining with the potassium to form potassic iodide; whilst the liquid will rise in the tube to its middle point, thus showing that half of the gas has disappeared. The residual gas may be shown to be hydrogen by its burning with the characteristic pale and intensely hot flame, whilst it is not a supporter of combustion. The iodine set free from the potassic iodide may be made apparent

by the formation of a beautiful blue colour on the addition of a little starch paste; and the chlorine, which has entered into combination with the potassium, may be precipitated by argentic nitrate.

**316.** A solution contains either carbonate of soda, chloride of sodium, or sulphide of sodium. How would you ascertain which of the three is present? *Jan. 1877.*

I should add some hydric chloride to the solution. A gas evolved with the smell of rotten eggs would indicate the presence of sodic sulphide ( $\text{Na}_2\text{S}$ ), a gas with no smell sodic carbonate ( $\text{Na}_2\text{CO}_3$ ). Should no gas at all be evolved, it would indicate the presence of sodic chloride ( $\text{NaCl}$ ).

Or, again, I might proceed thus:—I might put a portion of the solution into a small flask, fitted with a bent tube, dipping into a solution of plumbic acetate. If it became black, then the presence of sodic sulphide would be disclosed; if white, sodic carbonate; while if no change at all should occur, then I should know that sodic chloride was present.



## CHAPTER XV.

### BROMINE (Br).

(Monad, as in HBr.)

$$\frac{(\text{Br}_2) \text{ Molecular weight, } 160.}{\text{Molecular volume, } \boxed{\phantom{00}}} = 20 \text{ sp. gr.}$$

### IODINE (I).

(Monad, as in HI.)

$$\frac{(\text{I}_2) \text{ Molecular weight, } 254.}{\text{Molecular volume, } \boxed{\phantom{00}}} = 127 \text{ sp. gr.}$$

### FLUORINE (F).

(Monad, as in HF.)

Atomic weight = 19. Molecular volume unknown.

Or 80 grammes of Br and 127 grammes of I measure 11.2 litres.  
80 grains of Br and 127 grains of I measure 44.4 c. inches.



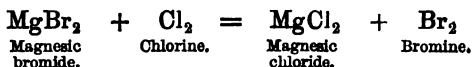
## BROMINE.

**317.\*** What are the sources of bromine ?

Bromine is found in the mineral waters of Kreuznach and Kissingen, in Germany, and in certain springs in Ohio and other parts of America. Sea water and sea plants contain it in minute quantities, but it is found in larger quantity in the waters of the Dead Sea. Bromine does not exist free in these sources, but combined, as magnesian bromide. It exists also as argentic bromide in the silver ores of Mexico. The mines of Chanarillo, in South America, yield it in abundance.

**318.\*** How is bromine prepared ?

*Abroad* it is prepared by extracting it from certain mineral waters, such as those of Kreuznach and Kissingen. In *England* it is extracted from the sea water from which common salt has been removed. This mother liquor<sup>1</sup> is commonly called salt oil, or bittern.<sup>2</sup> A current of chlorine is passed through the mother liquor; the chlorine, combining with the magnesium, sets the bromine free.

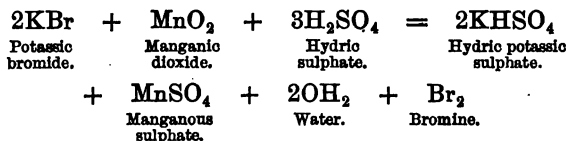


<sup>1</sup> The mother liquor is the liquid from which all the salts readily separable by crystallisation have been removed.

<sup>2</sup> *Salt oil*, so called by the workmen, in allusion to its density *bittern*, in allusion to its unpleasant taste of Epsom salts.

After this the bromine has to be separated from the magnesian chloride with which it is mixed. This is done by adding a little ether to the mixture, which dissolves the bromine only, and rises with it on the top. Thence it is decanted. To the decanted liquid some potassic hydrate (KHO) is then added; the bromine gets converted into potassic bromide and potassic bromate, which on being heated with charcoal are wholly converted into potassic bromide. Finally, with the potassic bromide is mixed a little manganic dioxide, and the mixture is distilled in a retort with hydric sulphate. The bromine is then set free and condensed into a receiver, kept cool by ice.

The reaction may be represented by:—



**319.** Give a brief description of the characteristic properties of bromine. *Jan. 1881.*

Bromine, like mercury, is liquid at the ordinary temperature, and is of a deep red colour. It is nearly three times as heavy as water, but is very volatile, emitting dense red vapours, which must not be breathed, as they irritate the nose and the throat considerably. In smell and in its disinfectant and bleaching powers it resembles chlorine. Bromine is but slightly soluble in water, though it dissolves readily in alcohol, and still more so in ether, yielding a solution of a yellow colour. Like chlorine, the aqueous solution of bromine is decomposed by the sunlight into hydric bromide and oxygen, and therefore should be kept in dark bottles.

**320.** In what respects do the chemical powers of bromine resemble those of chlorine? *June 1881.*

They resemble each other in the following points:— Each has the property of replacing iodine from its metallic solution; each, on account of its great affinity for hydrogen, can bleach vegetable colours, and is used as a disinfectant; and for the same reason the aqueous solution of each is decomposed by the sunlight into hydric chloride or bromide ( $\text{HCl}$ ,  $\text{HBr}$ ) and oxygen.

**321.** Two bottles are given you: one contains vapour of bromine, and the other vapour of nitric peroxide ( $\text{N}_2\text{O}_4$ ). How would you ascertain which of the two contains bromine? *June 1881.*

In the gaseous state each bottle would have the same reddish brown colour, but not so when cooled. I should, therefore, dip each bottle into icy cold water. The vapour of bromine would become a liquid of a dark red colour, whereas that of nitric peroxide (nitric tetroxide) would become a liquid of a yellow colour.

Again, I should shake up each bottle with water. The aqueous solution of bromine would be brown, that of nitric peroxide colourless. The first solution would discolour blue litmus; that of the second would make it pass from blue to red.

## IODINE.

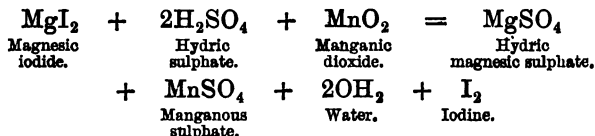
**322.\*** Where does iodine chiefly occur?

It exists in very small quantities in the ocean; but it is never extracted therefrom directly as the fuci, sponges, and other marine plants take it from the sea

water and store it up, as it were, in their own tissues. These, when burnt, give an ash which goes by the name of *varec* or *kelp*, which contains small quantities of iodine in the form of sodic iodide ( $\text{NaI}$ ). Glasgow manufactures a great quantity every year from the kelp gathered on the coasts of Scotland and Ireland. Iodine is also contained in the mineral waters of Saxon (Valais), in the silver ore of Mexico, and in the zinc ore of Silesia.

**323.\*** Give a short account of the preparation of iodine.

The sea weeds having been dried in the sun, are burned in shallow excavations at a low heat; the ashes (kelp) are then collected, and dissolved over and over again in water, in order to get rid of the less soluble chlorides and bromides. The mother liquor, or *iodine ley*, is then placed in a stoneware or leaden retort, into which hydric sulphate ( $\text{H}_2\text{SO}_4$ ) and manganic dioxide ( $\text{MnO}_2$ ) are introduced, the latter being added in small portions at a time. Then the retort is gently heated and the iodine is set free and condensed in large earthenware receivers. The reaction may be represented by the following equation:—



Iodine may also be obtained from the mother liquors of Chili saltpetre ( $\text{NaNO}_3$ ), but then it is treated with sulphurous dioxide ( $\text{SO}_2$ ).

**324.** What are the properties of iodine? *July*  
1849.

Iodine is a solid of crystalline appearance, but it is generally obtained in bluish black scales, resembling plumbago in lustre. Like bromine, it is **very volatile**, and therefore should be kept well corked. When fused it gives off beautiful **violet vapours**, which are 8 times heavier than air. Its smell resembles that of weak chlorine. Like chlorine, it disinfects and bleaches, though to a much less degree. Iodine is slightly soluble in water, but readily in alcohol, forming the 'tincture of iodine,' and in carbonic sulphide ( $\text{CS}_2$ ), forming a beautiful rich violet solution. It has the remarkable property of colouring a very large quantity of starch in blue. With due precaution<sup>1</sup> 1 part of iodine dissolved into a million parts of water may be clearly tested.

**325.** Two aqueous solutions are given you; one contains free bromine only, the other free iodine only. Describe how you would prove the presence of the bromine in the one solution and of the iodine in the other. *Jan. 1879.*

I should add to each solution a little cold starch paste. In that containing the bromine the starch will be turned yellow, but in that containing the iodine it will be turned blue. Or I should add to each solution a little carbonic disulphide ( $\text{CS}_2$ ). In that containing the bromine the carbonic disulphide will be turned brown, while in that containing the iodine it will be turned a beautiful violet colour.

**326.** If one bottle contained chlorine gas, and

<sup>1</sup> The precautions are:—If the iodine be present in an uncombined state, the starch paste should be perfectly cold; and if it be present in a combined state, then a little hydric chloride and potassic nitrite should be added besides.

another bromine vapour, how could you distinguish the two substances from each other? *June 1872.*

*Firstly.* I could distinguish them by their colour. Chlorine is of a yellowish green, while bromine is of a brownish red colour.

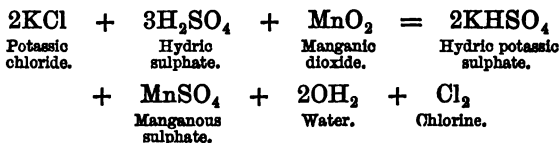
*Secondly.* I could distinguish them by their smell. Chlorine has a strong, suffocating smell, and bromine that of decayed sea-weeds. The first chiefly affects the lungs, the second the nose, and iodine the eyes.

*Thirdly.* I could distinguish them by shaking up each bottle with ether. The one in which the solution should become of a distinct brown colour would be that containing the bromine, while that in which the solution remains colourless would be that containing the chlorine.

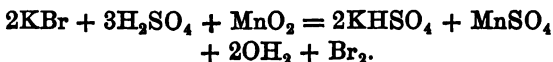
**327.** A white salt is known to be either chloride, bromide, or iodide of potassium. How would you ascertain with certainty which of these substances it is? *June 1875.*

As each of these salts is readily soluble in water, I should dissolve it. Then I should gently warm in a test tube a mixture of the solution with hydric sulphate and manganic dioxide.

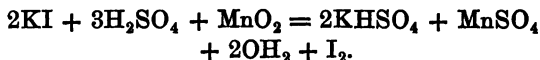
If it be potassic chloride, a yellowish green gas, viz. chlorine, would be set free.



If it be potassic bromide, a brownish red gas, viz. bromine, would be set free.



If it be potassic iodide, a purple gas, viz. iodine, would be set free.



Or I should add to the solution a little chlorine (or a solution of chloride of lime, or potassic nitrite) and shake it up with carbonic disulphide ( $\text{CS}_2$ ). If the carbonic disulphide should remain colourless the solution would contain a chloride; if brown, a bromide; and if violet, an iodide.

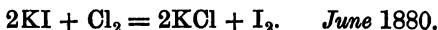
**328.** You are requested to ascertain whether a given black powder is composed of iodine or blacklead (graphite). How would you do so? *June 1879.*

How would you distinguish a piece of iodine from one of graphite? *June 1881.*

To ascertain whether a given black powder is iodine or blacklead, I should throw it on a hot brick. If it be composed of iodine the iodine will be at once completely reduced to a purple fume, whereas if it be composed of blacklead (graphite) the blacklead will remain unaffected.

The iodine will readily dissolve in alcohol, ether, potassic iodide, or in carbonic disulphide, but the graphite will not. The iodine by touch would stain the skin brown, and the graphite will not do so.

**329.** Explain the meaning of the equation:—



The meaning of this equation is that if chlorine be passed through a solution of potassic iodide, the chlorine replaces the iodine in the potassic iodide, at the same time setting the iodine free.

## FLUORINE.

**330.\* In what substances is fluorine found ?**

Fluorine is never found uncombined. It is most frequently found combined in calcic fluoride ( $\text{CaF}_2$ ), under the name of *fluor spar*. Small quantities of fluor spar are also found in the composition of certain soils, in several mineral and sea waters, and likewise in bones, shells, and corals. Fluorine is also one of the constituents of the mineral cryolite.

**331.\* How is it that fluorine has never yet been isolated for any length of time ?**

This is on account of the great facility with which it forms chemical compounds with nearly all substances, but chiefly with silicon—one of the elements of glass—and with hydrogen and the metals.

**332. You wish to test an aqueous solution for hydric fluoride. Describe how you would do so.**  
*June 1881.*

I should pour it over glass. If after a short time the glass be corroded, so as to have lost its transparency, then the liquid poured over it must be an aqueous solution of hydric fluoride, for no other acid has a similar property.

This test supposes that the liquid to be tested contains no other substance. If, however, it be suspected that the solution contains some other substance, first precipitate it by means of some hydric sulphate, and then proceed with the decanted liquid as above.

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## CHAPTER XVI.

### SULPHUR (S).

(Dyad, as in  $\text{SH}_2$ —Tetrad, as in  $\text{SO}_2$ —Hexad, as in  $\text{H}_2\text{SO}_4$ .)

Molecular weight, 64 (at  $1,000^\circ \text{C.}$ ), 192 (at boiling point).

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Molecular volume,

= 32, or 96 sp. gr.

### SULPHUROUS DIOXIDE ( $\text{SO}_2$ ).

Molecular weight, 64.

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Molecular volume,  = 32 sp. gr.

### SULPHURIC TRIOXIDE ( $\text{SO}_3$ ).

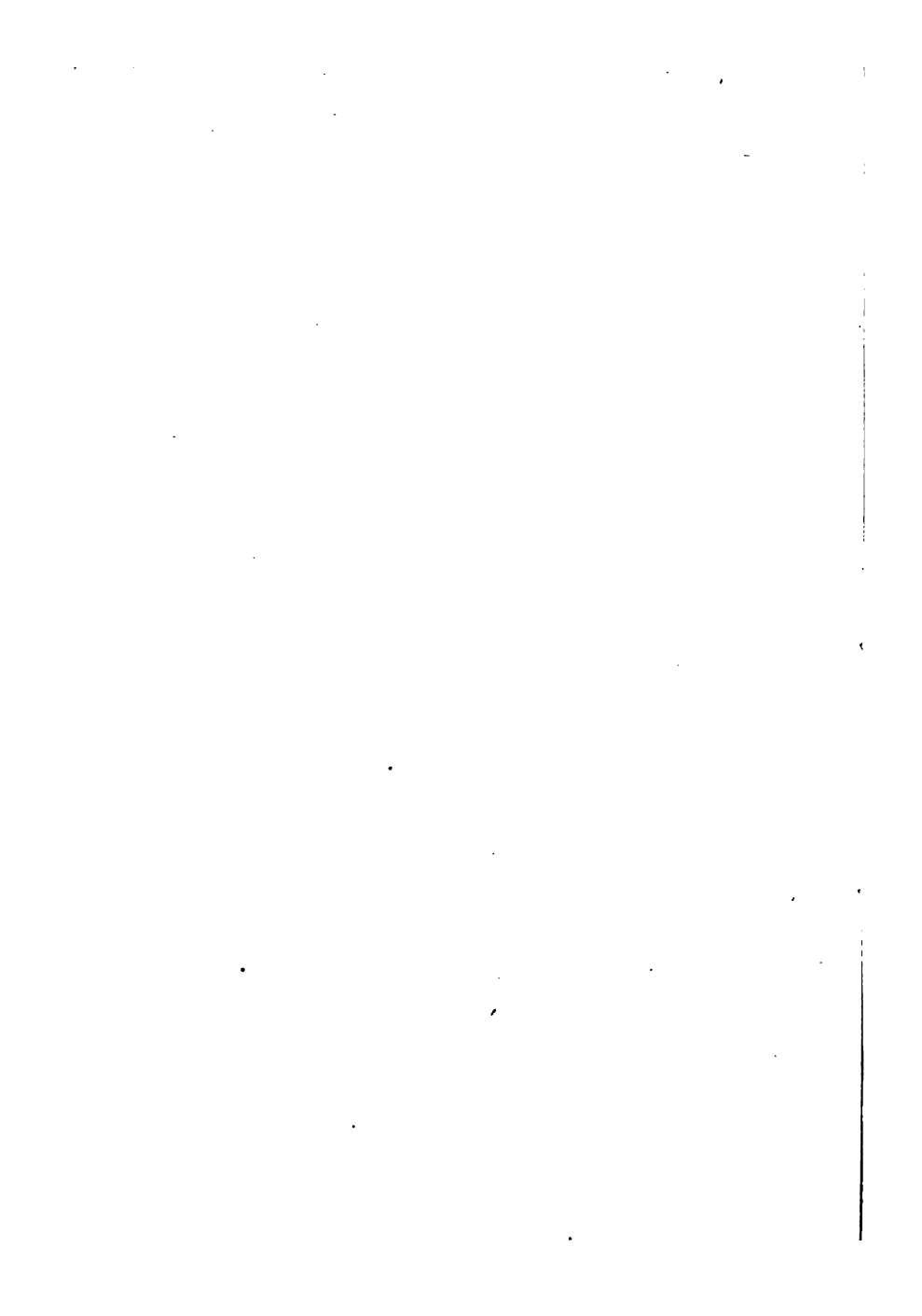
Molecular weight, 80.

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Molecular volume,  = 40 sp. gr.

32 or 96 grammes of S, 32 of  $\text{SO}_2$ , and 40 of  $\text{SO}_3$ , measure 11.2 litres.

32 or 96 grains of S, 32 of  $\text{SO}_2$ , and 40 of  $\text{SO}_3$ , measure 44.4 c. in.



## SULPHUR.

**333.** Name the chief substances from which the sulphur is obtained. *June 1868.*

The sulphur or brimstone of commerce is nearly all obtained from the rocky bodies which contain it in a free state. These rocky bodies are all found in the neighbourhood of the volcanic districts. It is also obtained from the slow combustion or distillation of '*pyrites*' and '*blendes*'—chiefly from the iron pyrite ( $\text{FeS}_2$ ).

**334.** What are the principal minerals containing sulphur? How is sulphur extracted? how purified? *Jan. 1864.*

The principal minerals containing sulphur are iron pyrite ( $\text{FeS}_2$ ), copper pyrite ( $\text{Fe}_2\text{S}_3 + \text{CuS}$ ), zinc blende ( $\text{ZnS}$ ), and galena or lead blende ( $\text{PbS}$ ).

Sulphur is extracted chiefly from the sulphurous clay which is found in the neighbourhood of volcanoes. Heat is applied to the mass containing sulphur, and the melted sulphur runs off and solidifies upon cooling. It is afterwards purified by the process of distillation, which operation is performed by heating the impure sulphur in large iron or earthen retorts and condensing the vapour in large chambers. If the walls of this chamber are not kept very cool the sulphur condenses

into a liquid, which is poured out into cylindrical wooden moulds, in which it solidifies to form the *roll sulphur*. If, on the contrary, the walls of the chamber are very cool, it condenses rapidly into a fine powder, known as 'flowers' of sulphur.

To extract sulphur from its minerals it is sufficient to subject them to a great heat and treat the sulphur in the manner it has been mentioned above. If extracted from the iron pyrites, the reaction may be thus represented :—



**335.** Describe the chief allotropic modifications of sulphur. *June 1868.*

The chief allotropic modifications of sulphur are three in number.

1. **The crystallised octahedric.** It occurs native, and it is also the form sulphur assumes when it is crystallised from its solution in carbonic disulphide. It is a remarkable fact that the two other allotropic modifications exhibit a constant tendency to assume this form.

2. **The oblique prismatic.** It is obtained from the slow cooling of sulphur which has been fused to 115° C.

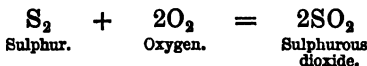
3. **The amorphous.** It is obtained when, after having been heated to 180°, the sulphur is slowly poured into cold water. The mass assumes the appearance of a soft, elastic, and transparent substance, of a dark yellow colour, much resembling caoutchouc in some of its properties. When left to itself, however, after a few days it returns to the crystallised form. It is insoluble in carbonic disulphide.

## SULPHUROUS DIOXIDE.

**336.** How is sulphurous acid obtained? *June 1868*  
—*Jan. 1870.*

What substance do you obtain when a piece of sulphur is burnt in oxygen? *June 1871.*

When a piece of sulphur is burned in oxygen, a pungent and very acid gas is obtained—namely, sulphurous dioxide (anhydride).



In the laboratory, however, it is usually prepared by the decomposition of hydric sulphate in a retort by means of mercury. The reaction may be represented by the following equation :—



Instead of mercury copper may be used, with similar results.

**337.** Describe the product of the combustion of sulphur in air. *Jan. 1864.*

The product of the combustion of sulphur in air is sulphurous dioxide. It is a colourless gas, possessing a suffocating smell. It is twice as heavy as air, and may easily be condensed to a liquid by a temperature of  $-10^\circ \text{C}$ . It is very soluble in water, forming a solution of hydric sulphite ( $\text{H}_2\text{SO}_3$ ). It does not support combustion, and is extremely poisonous. It is used on a large scale for the purpose of bleaching wool, silk, and

straw. It also has the remarkable property of checking animal decomposition and preventing putrefaction.

**338.\*** In what does the bleaching powers of sulphurous dioxide differ from that of chlorine?

Chlorine, when bleaching a vegetable colour, destroys it completely, so as to render it impossible to restore the colour. But this is not the case with sulphurous dioxide. Thus, if a bunch of violets or a red rose, somewhat moistened, be suspended in a vessel of the gas, or held over burning sulphur, its colour gradually disappears; but if the rose be then dipped in a weak solution of ammonia the colour will first be restored, and afterwards will be changed to green by the alkali.

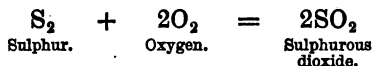
**339.** Describe and explain the reactions by which you would identify sulphurous acid gas. *Jan. 1870.*

To identify sulphurous dioxide I should try whether a candle would be extinguished in it and the gas not burn. If such be the case, I must still distinguish it from nitrogen and carbonic dioxide, both of which possess the like negative property. Nitrogen has no acid properties, whilst sulphurous dioxide possesses those in an eminent degree. Then, if I pour a few drops of lime-water into both jars, this lime-water would remain unaffected by the sulphurous dioxide, whilst the carbonic dioxide would cause it to become milky.

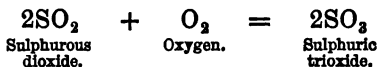
I could also identify it by its bleaching powers, which no other acid possesses. The colour of a red rose, if moistened a little, gradually disappears in this gas.

**340.** Describe how you could convert sulphurous acid into common sulphuric acid. *June 1871—Jan. 1882.*

When sulphur is burned in oxygen it seems unable to combine with more than two atoms of oxygen to form sulphurous dioxide.

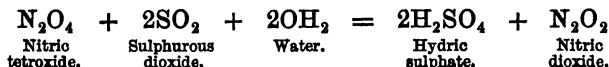


But once the gas formed, if it be mixed with half its volume of oxygen and passed through a tube containing heated sponge of platinum, then the two gases combine, and white fumes of sulphuric trioxide are given off.



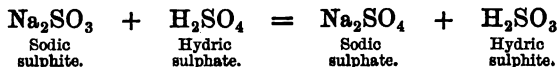
This sulphuric trioxide, when thrown into water, hisses as a hot iron would do. The solution has all the properties of ordinary hydric sulphate.

Another way of performing this conversion would be by adding an atom of oxygen to sulphurous dioxide through the medium of nitric tetroxide in the presence of water.



**341.** I pour dilute sulphuric acid upon sulphite of sodium. Give an equation showing the reaction which takes place. *June 1877.*

By doing so the sodium of the sulphite replaces the hydrogen of the hydric sulphate, forming at the same time sodic sulphate and hydric sulphite.



The hydric sulphite in its turn is soon decomposed

into water and sulphurous dioxide ( $\text{H}_2\text{SO}_3 = \text{OH}_2 + \text{SO}_2$ ).

**342.** How much sulphur and how much oxygen are contained in 100 grammes of sulphurous acid? *June 1868.*

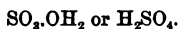
The formula of sulphurous dioxide (or anhydride) is  $\text{SO}_2$ , of which the molecular weight is  $32 + 32 = 64$ . Therefore, in order to find how much sulphur is contained in 100 grammes of  $\text{SO}_2$ , I solve

$64 : 100 :: 32 : x = 50$  grammes of sulphur, and consequently **50 grammes of oxygen.**

## SULPHURIC TRIOXIDE

AND

## HYDRIC SULPHATE.



**343.** What are the principal acids composed of sulphur and oxygen? How are these acids prepared? *July 1845—July 1850.*

How are the compounds of sulphur and oxygen formed? Give their formulæ. *Jan. 1876.*

The principal compounds of oxygen and sulphur are sulphurous dioxide and sulphuric trioxide. The formula of the former is  $\text{SO}_2$ , and that of the latter is  $\text{SO}_3$ . The preparation of sulphurous anhydride has been explained in No. 336; we shall now give that of sulphuric trioxide. **Strong Nordhausen acid** ( $\text{H}_2\text{S}_2\text{O}_7$ ) is **gently heated** in a retort connected with a receiver, which is kept very cold. The Nordhausen acid gives

up its additional molecule of sulphuric trioxide, and ordinary hydric sulphate remains.



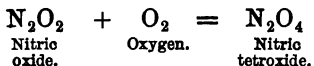
**344. How is sulphuric acid made?** Explain the chemical changes which take place in the process. *July 1844—July 1849—June 1870.*

**Sulphurous dioxide**, obtained by roasting iron pyrites in the presence of air, is introduced into a leaden chamber. Within the chamber **hydric nitrate** is generated by the action of hydric sulphate on sodic nitrate, and finally a **current of air** is made to pass through the chamber together with **steam** supplied from a boiler. Hydric sulphate is obtained through the following reactions:—

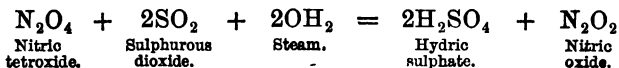
a. The hydric nitrate is decomposed by the sulphurous dioxide, with formation of nitric oxide and hydric sulphate.



b. The nitric oxide, when in the presence of free oxygen, is at once changed into nitric tetroxide, causing the appearance of red fumes.



c. The nitric tetroxide is acted on by the sulphurous dioxide, which deprives it of one of its atoms of oxygen to form hydric sulphate.



And, again,  $\text{N}_2\text{O}_2$  is converted into  $\text{N}_2\text{O}_4$ , which by yield-

ing one atom of O changes  $\text{SO}_2$  into  $\text{SO}_3$ , and  $\text{SO}_3$  in the presence of water changes into  $\text{H}_2\text{SO}_4$ .

**345.** Describe the composition and properties of sulphuric acid. *July 1848—July 1849.*

The composition of hydric sulphate is expressed by the formula  $\text{H}_2\text{SO}_4$ ; that is to say that it is composed of 2 atoms of hydrogen, 1 atom of sulphur, and 4 atoms of oxygen.

The oil of vitriol of commerce is a dense oily-looking liquid, without odour. Its specific gravity compared with that of water is 1.842. It is intensely caustic, and chars almost all organic substances, owing to its powerful attraction for moisture. It may therefore be used for the purpose of drying gases. When mixed with water in the proportion of 2 of acid to 1 of water, it gives out great heat. It forms with bases the important class of salts called sulphates.

**346.** Write down the formulæ (1) of the oxides of sulphur, (2) of the substances formed when they are brought in contact with water, (3) of the neutral and acid sulphate and sulphite of potassium. *June 1876.*

1. The formulæ of the oxides of sulphur are  $\text{SO}_2$  and  $\text{SO}_3$ .

2. When in contact with water, these formulæ become  $\text{H}_2\text{SO}_3$  and  $\text{H}_2\text{SO}_4$ .

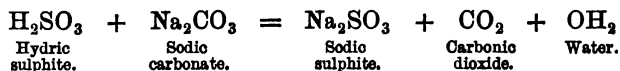
3. The formulæ of the neutral potassic sulphite and sulphate are  $\text{K}_2\text{SO}_3$  and  $\text{K}_2\text{SO}_4$ .

4. The formulæ of the acid potassic sulphite and sulphate are  $\text{KHSO}_3$  and  $\text{KHSO}_4$ .

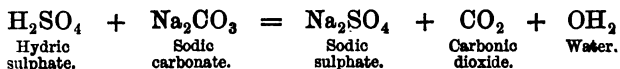
**347.** Describe the action of sulphurous and sulphuric acid upon water and upon a solution of carbonate of soda. *Jan. 1876.*

The action of sulphurous dioxide upon water is the formation of the hydrate  $\text{H}_2\text{SO}_3$ , and that of sulphuric trioxide is  $\text{H}_2\text{SO}_4$ , or oil of vitriol.

The action of hydric sulphite upon sodic carbonate is the formation of sodic sulphite.



The action of hydric sulphate upon sodic carbonate is the formation of sodic sulphate.



**348.** How would you ascertain whether a specimen of an acid consisted of sulphuric or of nitric acid? *June 1871.*

I should pour a few drops of both acids on some organic substance, say sugar. In the case of hydric sulphate this will at once be charred, whilst the lump of sugar will not be charred by the hydric nitrate.

Again, I should throw in both liquids a silver or copper coin. With hydric sulphate both coins will remain intact; with hydric nitrate, on the contrary, both coins will be dissolved with evolution of dark red fumes.

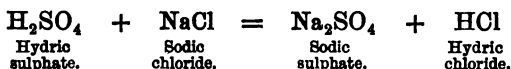
Also a solution of baric chloride ( $\text{BaCl}_2$ ) poured into the vessel containing hydric sulphate will cause the appearance of a white heavy precipitate of baric sulphate, but not so when poured into the vessel containing the hydric nitrate.

**349.** A sample of vinegar is supposed to be adulterated with sulphuric acid. How would you ascertain the presence of sulphuric acid in vinegar? *Jan. 1869.*

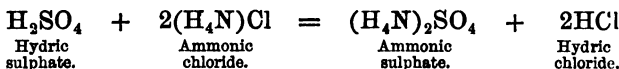
I should pour into the adulterated vinegar a few drops of a solution of baric chloride ( $\text{BaCl}_2$ ). If a white precipitate is formed which is not soluble in hydric nitrate, then the precipitate was baric sulphate, which could not have been formed but through the action of some sulphate. Thus I conclude that the vinegar was adulterated with hydric sulphate.

**350.** Express by equations the reactions which occur when sulphuric acid is heated together with common salt, with sal-ammoniac, with nitre, and with copper respectively. *June 1875.*

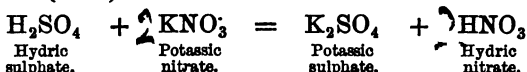
1. When hydric sulphate is heated with common salt :—



2. When hydric sulphate is heated with sal-ammoniac (ammonic chloride) :—



3. When hydric sulphate is heated with potassic nitrate (nitre) :—



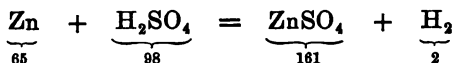
4. When hydric sulphate is heated with copper :—



**351.** State in words and describe by symbols the action of diluted sulphuric acid upon zinc and upon oxide of zinc respectively. Mention the proportion in

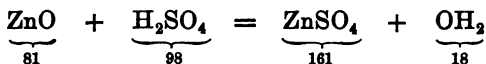
which each of these substances employed or produced enters into the reaction. *Jan.* 1862.

The action of hydric sulphate upon zinc constitutes the ordinary method of obtaining free hydrogen. The zinc expels the hydrogen from its combination in the hydric sulphate, leaving in solution in the bottle zincic sulphate. The equation expressing this reaction is :—



The numbers 65, 98, 161, and 2 express the proportion by weight of the substances used and produced.

The action of diluted hydric sulphate on zincic oxide is a mere dissolving of the oxide in the acid with formation of the salt, zincic sulphate, and water. The action may be expressed thus :—



The numbers 81, 98, 161, and 18 express the proportion by weight of the substances used and those that have been obtained.

**352.** What is the difference between a sulphite and a sulphate? *Jan.* 1871—*June* 1880—*Jan.* 1881.

The difference in *composition* is that a sulphate contains 4 atoms of oxygen, and a sulphite contains 3.

The difference in *their formation* is that a sulphate is formed by the substitution of a metal for the hydrogen in hydric sulphate ( $\text{H}_2\text{SO}_4$ ), and a sulphite is formed by the substitution of a metal for the hydrogen in hydric sulphite ( $\text{H}_2\text{SO}_3$ ).

**353.** Give tests for distinguishing between soluble sulphites and sulphates. *June* 1876—*June* 1880.

To test a *sulphite*, pour a few drops of its solution into a tube in which hydric sulphate is acting on zinc: hydric sulphide or sulphuretted hydrogen is given off. To prove which, hold over the tube a paper moistened with lead acetate: it turns at once black.

Or warm the sulphite with a solution of auric chloride: the gold will be precipitated.

Or, finally, pour on the solution of a sulphite a few drops of baric chloride: a white precipitate of baric sulphite is formed, which is *soluble* in hydric chloride. On the contrary, if the same substance be poured on the solution of a sulphate, a white precipitate of baric sulphate is formed, but it is *insoluble* in hydric chloride.

## CHAPTER XVII.

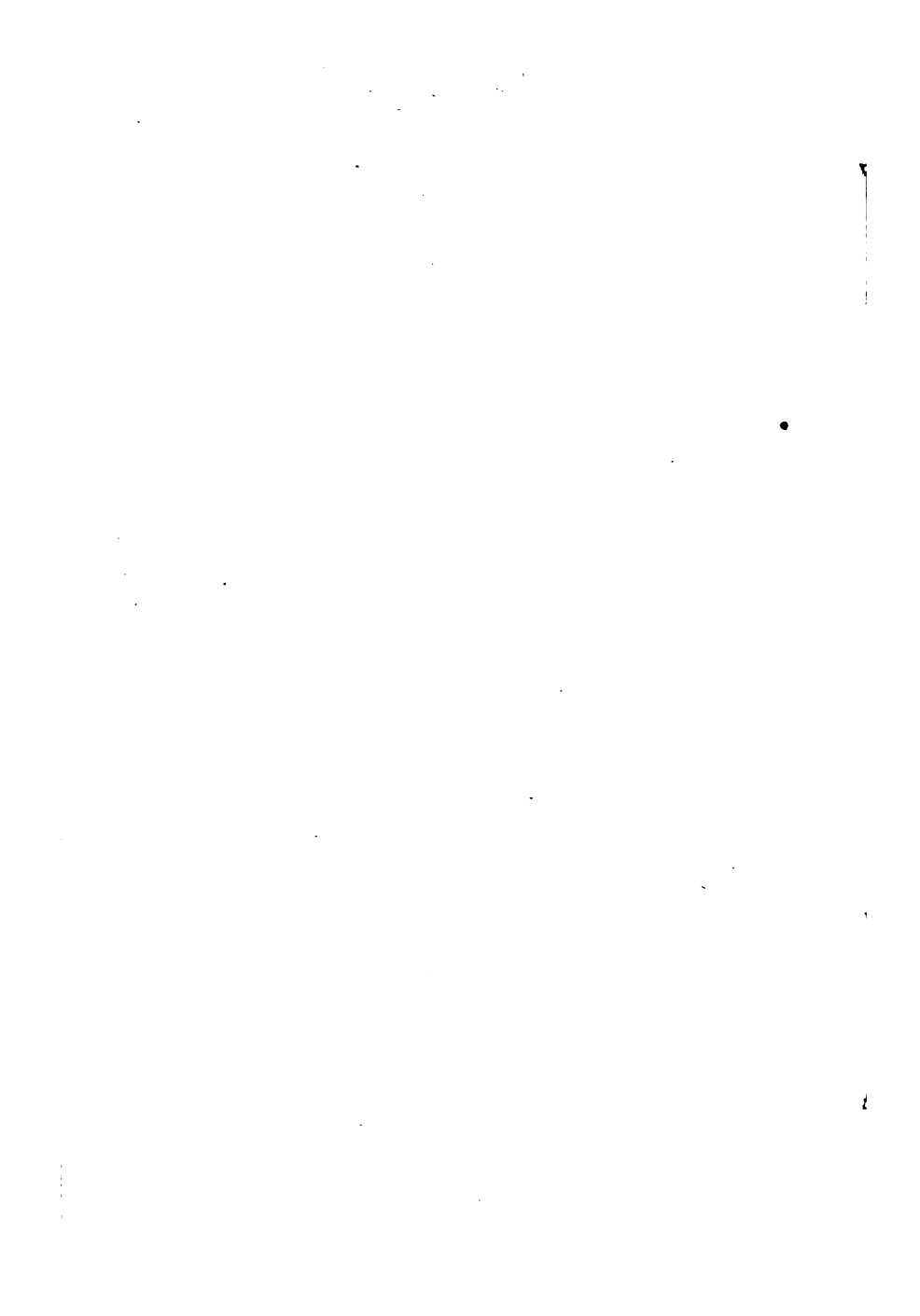
### HYDRIC SULPHIDE ( $\text{H}_2\text{S}$ ).

(Sulphuretted Hydrogen—Hydrosulphuric Acid—Hydrogen Sulphide.)

$$\frac{\text{Molecular weight, 34.}}{\text{Molecular volume, } \boxed{\phantom{00}}} = 17 \text{ sp. gr.}$$

Or 17 grammes of  $\text{H}_2\text{S}$  measure 11.2 litres.

17 grains of  $\text{H}_2\text{S}$  measure 44.4 cubic inches.



## HYDRIC SULPHIDE.

**354.** What are the tests you would employ in order to detect the presence of a dissolved sulphate, chloride, sulphide, and nitrate? *June 1870.*

In order to detect the presence of a *dissolved sulphate*, I should pour into the solution a few drops of **baric chloride**. If a white heavy precipitate is formed, insoluble in hydric nitrate, then the body in solution was a sulphate.

In order to detect the presence of a *dissolved chloride*, I should pour into the solution a few drops of **argentic nitrate**. A white precipitate is formed, which, if insoluble in hydric nitrate, but soluble in ammonia, is a test that the body in solution was a chloride.

In order to detect the presence of a *dissolved sulphide*, pour into the solution a few drops of **hydric chloride**, and a strong smell of hydric sulphide will be noticed, and moistened lead-paper, held over the vessel from which the gas is issuing, will turn black.

Finally, in order to detect the presence of a *dissolved nitrate*, I should add to the solution a few drops of **ferrous sulphate** ( $\text{FeSO}_4$ ). After having it shaken, I should pour very carefully down the side of the tube a little concentrated **hydric sulphate** ( $\text{H}_2\text{SO}_4$ ), to form a distinct layer at the bottom. If a nitrate be present, a brown ring will be formed at the junction of the two liquids.

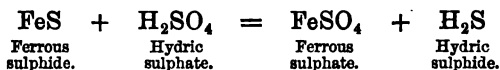
**355.\*** What are the natural sources of hydric sulphide?

Hydric sulphide is evolved from **volcanoes**. It occurs also in solution in many **mineral springs**, such as those of Harrogate, which owe their offensive smell and taste to the presence of the gas derived from the decomposition of pyrites. It is also produced during the decomposition of many animal and vegetable substances which contain sulphur.

**356.** Explain by means of symbols the formation of sulphuretted hydrogen from ferrous sulphide ( $\text{FeS}$ ) and hydric sulphate (sulphuric acid,  $\text{H}_2\text{SO}_4$ ). *Jan. 1875.*

**357.** I pour dilute sulphuric acid upon sulphide of iron. Give the equation showing the reaction which takes place. *June 1877.*

The **hydrogen** of the hydric sulphate is **displaced** by the **iron** of the ferrous sulphide, thus forming **ferrous sulphate** and evolving hydric sulphide, according to this equation:—

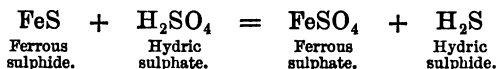


**358.** What is sulphuretted hydrogen? How is it prepared? What are its principal uses in the laboratory? *July 1862.*

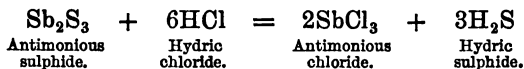
Hydric sulphide or sulphuretted hydrogen is a **colourless gas** having a smell of rotten eggs. It is prepared chiefly in two ways:—

1. By the action of **hydric sulphate** on a **sulphide**, commonly sulphide of iron (pyrite). The iron displaces

the hydrogen, which combines with the sulphur according to this equation:—



2. By the action of strong hot hydric chloride on antimonious sulphide. A reaction takes place similar to the above, as is seen in the equation:—



Its principal use in the laboratory is as a test for the distinction of metals, for when passed into their compounds in solution it produces precipitates of their sulphides, which frequently have a characteristic colour.

**359.\*** Enumerate the chief properties of hydric sulphide.

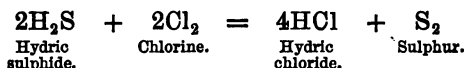
It is a colourless gas, having the odour of rotten eggs. It burns with a pale bluish flame, depositing sulphur if the supply of air be insufficient for complete combustion, but it does not support combustion. When breathed it acts as a very violent poison. However mineral waters which contain it dissolved in small quantities possess medicinal properties. The waters which contain it dissolved are called 'hepatic waters' (Harrogate, Moffat, and Aix-la-Chapelle waters). Heat, chlorine, bromine, and iodine decompose it. Under a pressure of 17 atmospheres it is reducible to a colourless and extremely mobile liquid.

**360.** Explain the action of chlorine on sulphuretted hydrogen. *Jan. 1865.*

How can sulphuretted hydrogen most conveniently

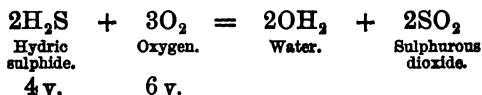
be decomposed when diffused in the air of a room?  
*July 1862.*

When sulphuretted hydrogen is diffused in a room, the most convenient process of decomposing it is by the action of chlorine, the chlorine itself being expelled by some acid out of the bleaching powder, or chloride of lime. The chlorine combines with the hydrogen of the hydric sulphide, setting the sulphur free, thus forming two new compounds entirely free from any deleterious properties.



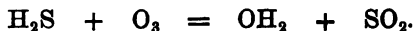
**361.** What bodies are formed by the combustion of sulphuretted hydrogen in air? How many cubic centimetres of pure oxygen are necessary for the combustion of 100 cubic centimetres of sulphuretted hydrogen?  
*June 1872.*

When hydric sulphide (sulphuretted hydrogen) is burned in a limited supply of air, it burns with a pale bluish flame, forming water and sulphurous dioxide, according to this:—



Thus we have 4 : 6 :: 100 : x, or x=150 cubic centimetres of oxygen.

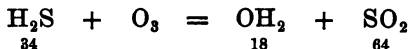
**362.** The combustion of hydric sulphide in air is represented by the equation:—



How much sulphurous acid and how much water

can be formed from 100 grains of hydric sulphide ( $H=1, S=32, O=16$ )? *June 1880.*

NOTE.—This equation differs from the preceding ones in being an atomic equation, not a molecular one.



To find the quantity of water we have  $34 : 18 :: 100 : x = 52.94$  grains.

To find the quantity of sulphurous dioxide,  $34 : 64 :: 100 : x = 188.24$  grains.

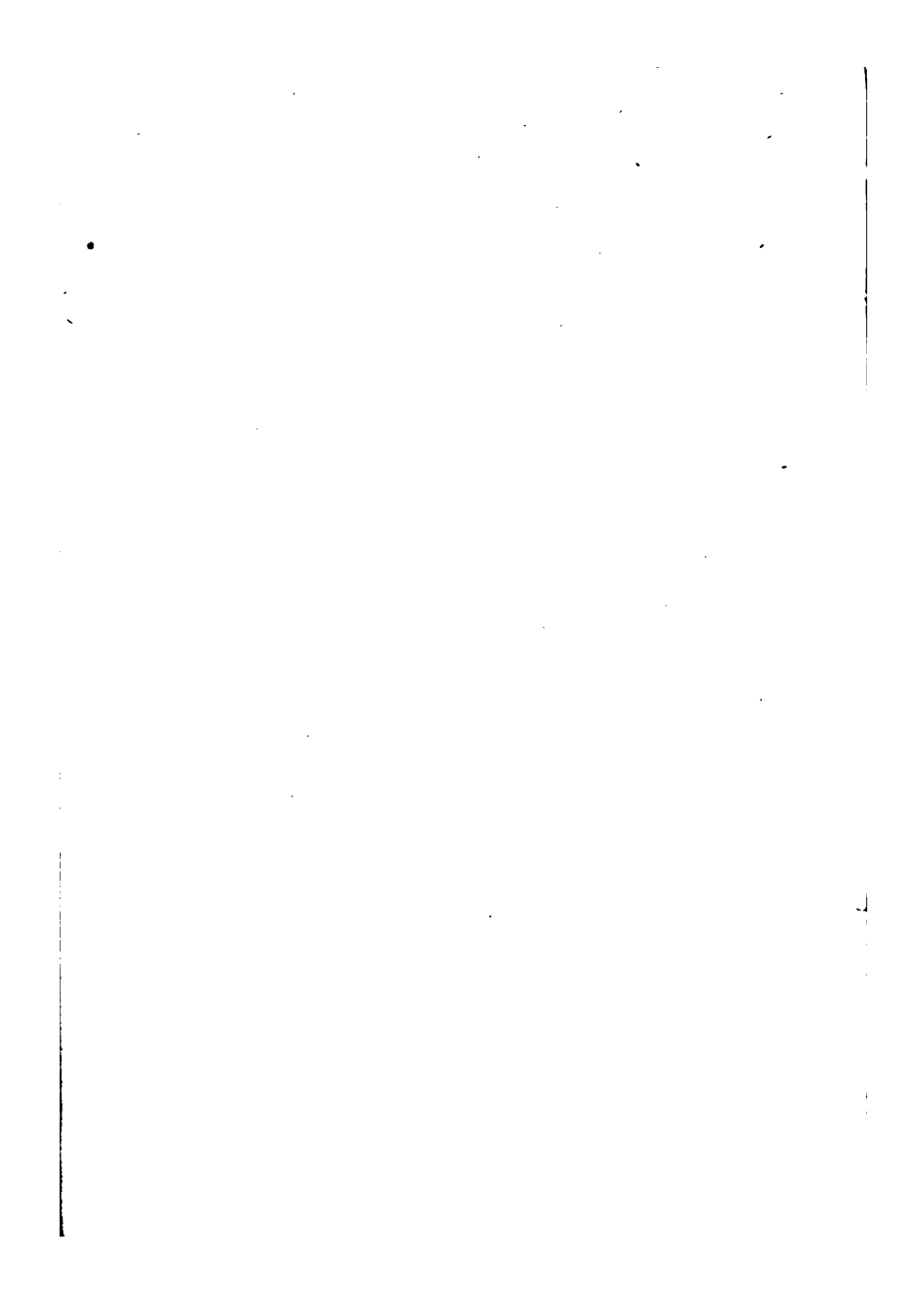
**363.** How does sulphuretted hydrogen act on a solution of litharge ( $PbO$ ) in hydric nitrate ( $NHO_3$ )? *Jan. 1875.*

It forms a black precipitate of sulphide of lead, which is insoluble in ammoniac sulphide.

**364.** How do you prove that hydric sulphide is a compound of sulphur and hydrogen? *Jan. 1875—June 1879.*

I fill a jar of this gas and kindle it. The gas burns with a pale bluish flame, owing to the combustion of sulphur, as is proved by the formation of *sulphurous dioxide*. That this gas is formed is proved by the fact that it bleaches moist litmus paper, and that the colour of the litmus will reappear if immersed in a diluted solution of hydric chloride. It is true that chlorine also bleaches litmus paper, but the colour in this case can never be restored.

That hydrogen is present is proved by the fact that water has been formed, of which hydrogen is one of the constituents. To make sure, however, that water is present, I drop into it a small ball of potassium, which in water instantly ignites.



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## CHAPTER XVIII.

### SILICON (Si).

(Tetrad, as in  $\text{SiCl}_4$ .)

Atomic weight, 28.

### SILICIC DIOXIDE ( $\text{SiO}_2$ ).

(Silica—Silicic Anhydride.)

Molecular weight, 60.



## SILICON.

**365.\*** Does silicon exist free in nature ?

No, but it is found combined with oxygen in silex or flints, granites, quartz, agate, and chalcedony. It is the most abundant solid compound of the earth's crust.

**366.\*** From what mineral is silicon obtained ?

It is obtained from potassic silico-fluoride ( $2\text{KF} \cdot \text{SiF}_4$ ). If this substance be heated with potassium and zinc, the temperature not being allowed to rise too high, potassic fluoride (KF) will be formed, and the silicon will dissolve in the melted zinc and crystallise on cooling. Then, upon adding hydric chloride, the zinc is dissolved and the crystals of silicon will be left.

**367.\*** Which are the allotropic modifications of silicon ?

Silicon, like carbon, exists in three allotropic modifications.

1st. **Amorphous silicon**, which is a dull brown powder insoluble in water and in hydric nitrate and sulphate, but soluble in warm potassic hydrate and in hydric fluoride when heated with it. It burns brilliantly in oxygen, being converted into silica.

2nd. **Graphitoid silicon**, which exists in hexagonal prisms.

3rd. **Crystallised silicon**, which crystallises in six-sided prisms.

**368.\*** How is amorphous silicon converted into graphitoid silicon ?

By raising it to a high temperature it is converted into graphitoid silicon. The properties then are changed: its specific gravity increases, and it is no more acted upon, either by hydric fluoride or by potassic hydrate, and it will no longer burn in oxygen.

**369.\*** How many combinations does silicon form with oxygen ?

It forms with oxygen but a single oxide, namely, silica ( $\text{SiO}_2$ ).

## SILICIC DIOXIDE.

**370.** Write the formula of silica. *Jan.* 1882.

The formula of silica is  $\text{SiO}_2$ .

**371.** What are the natural substances in which silica occurs ? *June* 1860.

Name minerals which contain silica. *Jan.* 1882.

Silica occurs in the stems of plants. It occurs almost pure in quartz, rock crystal, also in chalcedony, agates, flints, white sand, and sandstone, and in combination in many rocks and minerals, as granite, basalt, &c. It is also found in great quantities dissolved in the hot water issuing from the fissures of the soil, forming the 'geysers' of Iceland, the *suffioni* of Tuscany, and the waters of the Yellowstone River in America. These

waters on cooling deposit their silica on surrounding objects as *petrifications*. It is generally believed that chalcedony and the various agates and onyxes were formed in this way.

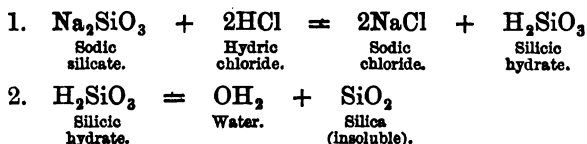
**372.\*** What are the properties of silica ?

Silica is a snow white, gritty powder, which, after being strongly heated, is quite insoluble in water and acids, except hydric fluoride. It dissolves easily in a boiling solution of potassic hydrate. In nature it is found crystallised as quartz. It is very hard, for it scratches glass. It melts when exposed to the oxy-hydrogen flame.

**373.** Describe how you would render silica soluble in aqueous hydrochloric acid, and how the soluble modification of this substance can be converted into the insoluble form. *Jan. 1869.*

I should first heat the silica with sodic carbonate, thereby forming a sodic silicate, and afterwards add to it hydric chloride, which partly decomposes the silicate and partly dissolves the separated silicic hydrate. Now, if I evaporate this liquid to perfect dryness by a temperature of about  $100^{\circ}\text{C}$ ., it loses its solubility, becoming silicic dioxide.

The equations of this twofold operation are :—



**374.** A crystal is given to you, and you are requested to ascertain by a chemical experiment whether it is a

diamond or a common rock crystal. Describe an experiment which will furnish the required information.  
*June 1874.*

I should heat the crystal to redness and then plunge it into a jar containing oxygen. If the crystal be a diamond it would burn with flame, with the formation of carbonic dioxide; whereas if it be the rock crystal it would not burn.

**375.** A splinter of a colourless, transparent solid body is given to you. How could you ascertain, (a) by physical tests, (b) by chemical tests, whether this is a glass or diamond?

*By Physical Tests.*—1. Glass, when dropped in glycerine, is scarcely seen, because both have nearly the same index of refraction; whilst diamond, having a much greater index of refraction, is clearly seen in the glycerine.

2. Diamond has a great dispersive power; glass has but little.

3. Diamond scars glass, but glass does not scratch the diamond.

4. Glass breaks with great facility, but diamond does not.

*By Chemical Tests.*—1. Glass becomes tarnished by vapours of hydric fluoride, and diamond does not.

2. Diamond burns in oxygen, and glass does not do so.

**376.** How could you prove that the constituent of flint has properties similar to other acids, and how can this substance be obtained dissolved in water?  
*June 1876.*

I could prove that the constituent of flint has

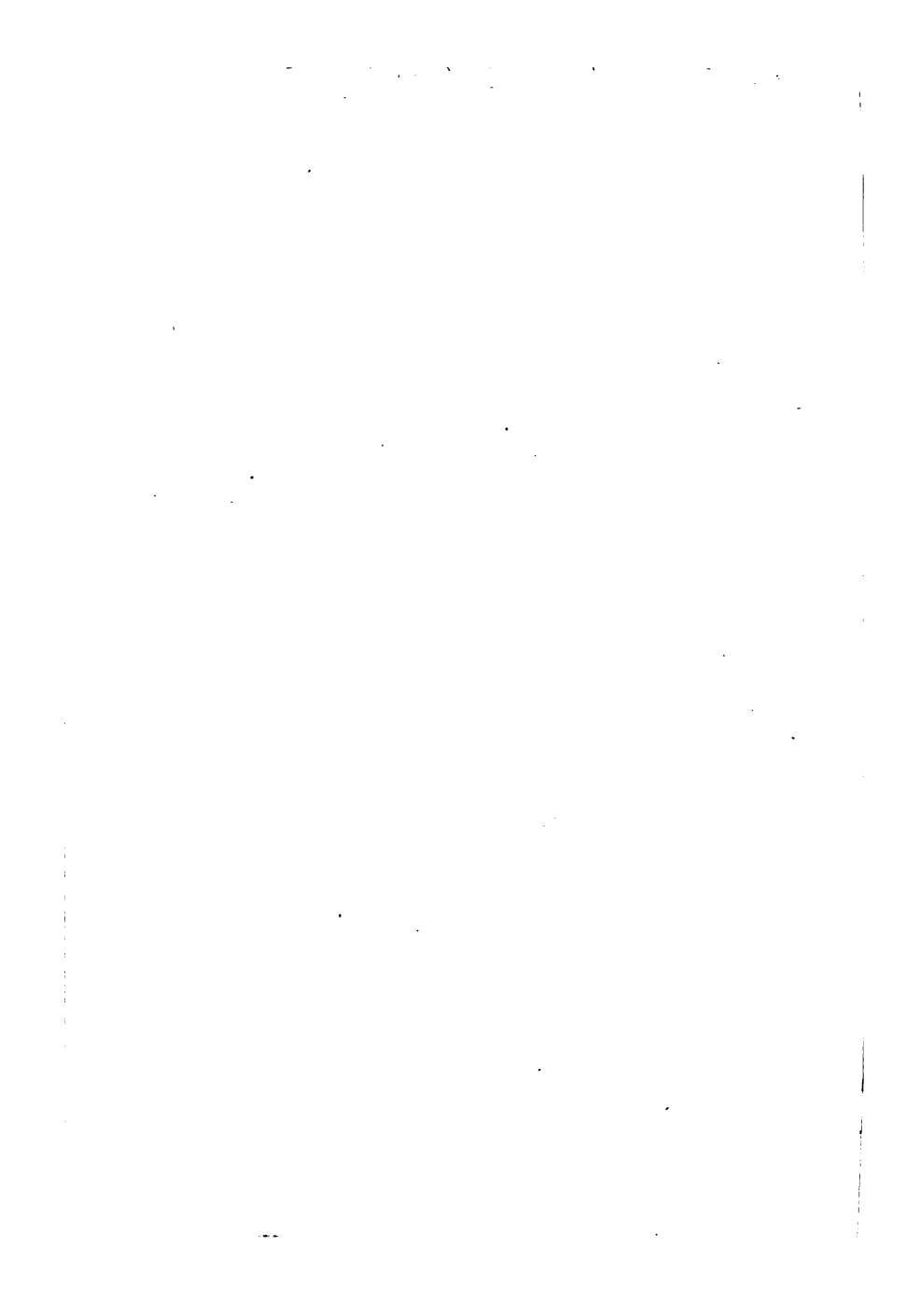
properties similar to those of other acids by heating in a platinum crucible some sodic carbonate. The acid of the salt (carbonic dioxide) is expelled, and the silica of the flint takes its place, forming sodic silicate. This shows that silica must be an acid, for otherwise it could not expel an acid.

To obtain silica dissolved in water, add to sodic silicate hydric chloride. This decomposes the silicate, forming a gelatinous precipitate of silicic hydrate, which may be dissolved in water.

**377.** Flint is said to be composed of silica, which, although it has no sour or acid taste, is also called silicic acid. Why is it so called? *Jan. 1866—Jan. 1874.*

Why is silica called silicic acid? *Jan. 1882.*

It is so called from the similarity of its action to that of other known acids. Thus it displaces *anhydrous* acids from their compounds when heated with them, and likewise stronger acids displace it from its compounds in solution. *E.g.* if sodic carbonate and silica be heated together, they form sodic silicate with evolution of carbonic dioxide. But the expelled gas—carbonic dioxide—is an acid; therefore the body that expelled that gas from the salt it was combined with, must also be an acid.



## CHAPTER XIX.

### PHOSPHORUS (P).

(Usually a **Triad**, as in  $\text{PH}_3$ ; frequently a **Pentad**, as in  $\text{PCl}_5$ .)

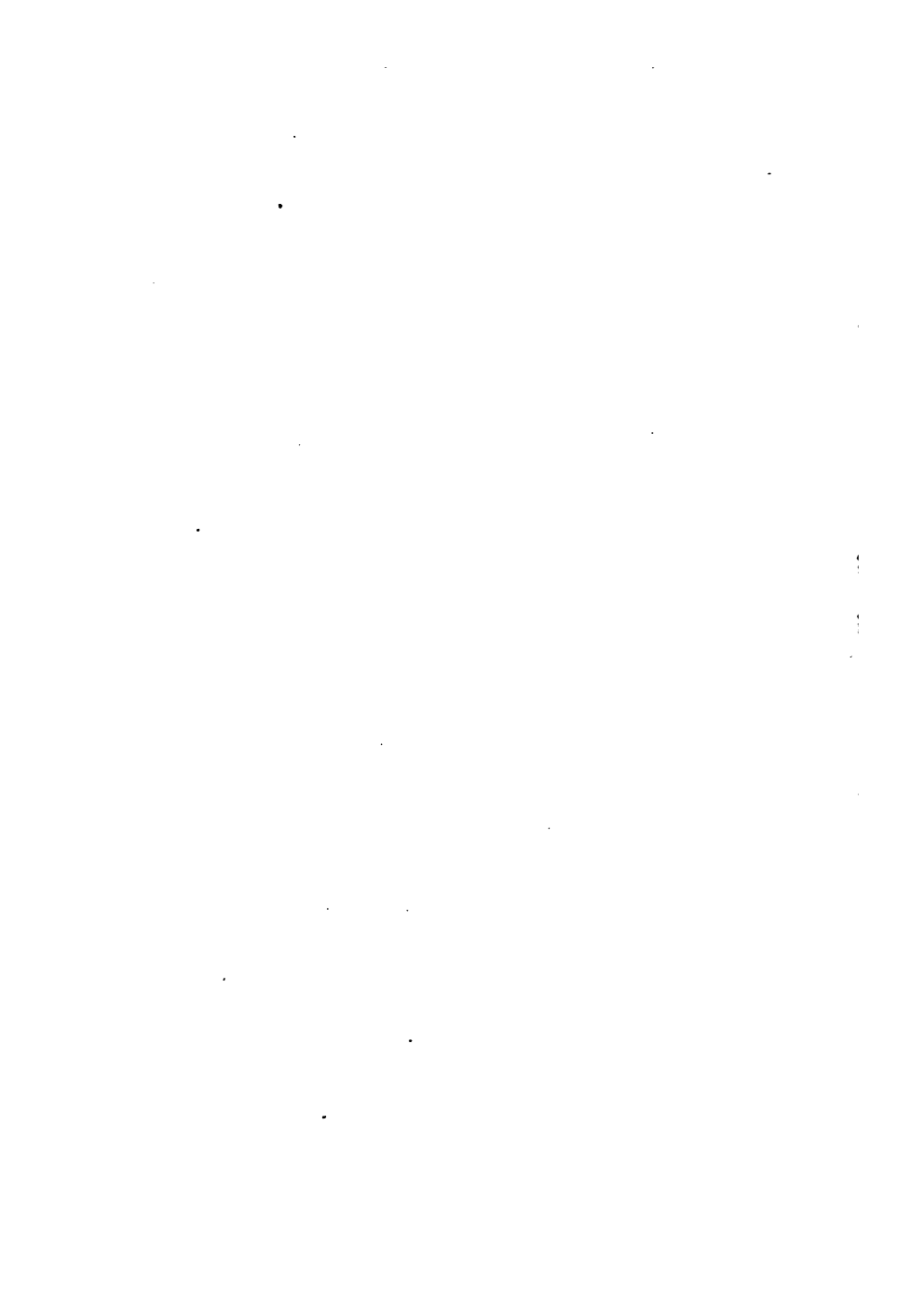
$$\frac{(\text{P}_4) \text{ Molecular weight, } 124.}{\text{Molecular volume, } \boxed{\phantom{00}}\boxed{\phantom{00}}\boxed{\phantom{00}}} = 31 \text{ sp. gr.}$$

### PHOSPHORIC PENTOXIDE ( $\text{P}_2\text{O}_5$ ).

(Phosphoric Anhydride—Phosphoric Acid.)

$$\frac{\text{Molecular weight, } 142.}{\text{Molecular volume, } \boxed{\phantom{00}}\boxed{\phantom{00}}} = 71 \text{ sp. gr.}$$

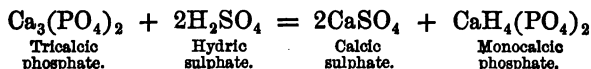
Or 31 grammes of P and 71 of  $\text{P}_2\text{O}_5$  measure 11·2 litres.  
31 grains of P and 71 of  $\text{P}_2\text{O}_5$  measure 44·4 c. in.



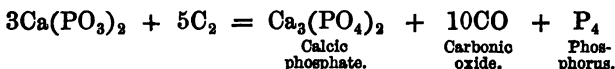
## PHOSPHORUS.

**378.\*** How is phosphorus prepared from bone earth?  
*July 1859—July 1861.*

The bone earth, mixed with diluted hydric sulphate, is stirred and then left at rest for some hours. Then fresh water is added, afterwards filtered. During this operation the water has taken up in solution the calcic phosphate  $[\text{CaH}_4(\text{PO}_4)_2]$ , leaving behind the insoluble calcic sulphate.



This solution of calcic phosphate is then evaporated, mixed with powdered charcoal, and then heated in an iron vessel until every trace of water is expelled. In this operation the calcic tetrahydric phosphate or calcic superphosphate has changed into calcic metaphosphate  $[\text{Ca}(\text{PO}_3)_2]$ . This last body is again heated with carbon up to a high temperature, at which it decomposes, forming



The mixture is heated in a clay retort, under which action the carbonic oxide escapes and the phosphorus is condensed into the water.

**379.** How much phosphorus, calcium, and oxygen are contained in 100 lbs. of bone ash, if the composition of that substance is represented by the formula  $3[\text{Ca}_3(\text{PO}_4)_2]\text{CaCO}_3$ ? [ $\text{Ca} = 40, \text{P} = 31, \text{C} = 12, \text{O} = 16.$ ] *Jan.* 1882.

The molecular weight of  $3[\text{Ca}_3(\text{PO}_4)_2]\text{CaCO}_3$  is:—  
 (P) 186 + (Ca) 400 + (O) 432 + (C) 12 = 1030, or  
 1030 : 100 :: 186 lbs. of P is :  $x = 18.06$  lbs. of phosphorus  
 1030 : 100 :: 400 lbs. of Ca is :  $x = 38.83$  lbs. of calcium  
 1030 : 100 :: 432 lbs. of O is :  $x = 41.94$  lbs. of oxygen.

**380.\*** What are the sources of phosphorus?

Phosphorus is never found native, but, combined with oxygen, calcium, and magnesium, it is widely distributed in many rocks and soils. It is a constituent of the plants used by men and beasts as food. The bony skeleton owes its strength to calcic and magnesian phosphate and carbonate. Phosphorus exists also in other states of combination in the flesh, blood, brain, milk, and other secretions of animals.

**381.** Why is phosphorus kept under water? *June* 1866.

Phosphorus is kept under water because when kept in the air it slowly combines with the oxygen of the air, forming white fumes of phosphoric pentoxide, and if the weather be warm and dry it would take fire spontaneously.

**382.** What are the allotropic conditions and the chemical characters of phosphorus? *July* 1859.

Phosphorus is, at the ordinary temperature, a soft, transparent, pale yellow solid, with a smell reminding us of garlic. It is insoluble in water, in which it is

kept in order to prevent spontaneous combustion. It dissolves in the volatile oils and in naphtha, but chiefly in carbonic disulphide, from which it may be obtained crystallised. It melts at  $42^{\circ}$  and boils at  $288^{\circ}\text{C}$ . It burns with a bright flame, and may be kindled from the mere friction or heat of the hand. It is luminous in the dark, owing to its slow combination with the oxygen of the air.

Its allotropic forms are the transparent yellow phosphorus, the white phosphorus, and the amorphous opaque red phosphorus.

**383.** How is phosphorus transformed into the red modification? *July 1861.*

How is red phosphorus made from clear phosphorus? *June 1866—Jan. 1873.*

Dry phosphorus is slowly heated in a sealed tube from which the air has been excluded. In order to heat it slowly, the operation is done in an oil bath, which boils at the temperature of about  $230^{\circ}\text{C}$ . Then expel the air, which is best done by introducing into the flask hydrogen or carbonic dioxide. After this operation has continued for several hours, but not above the temperature of  $230^{\circ}\text{C}$ ., the phosphorus will have been transformed into the red amorphous modification.

**384.** By what experiments could you prove that common phosphorus and red or amorphous phosphorus are allotropic modifications of the element phosphorus? *June 1871—June 1878.*

**385.** How would you prove that red phosphorus is an allotropic modification of the phosphorus which melts at  $44^{\circ}\text{C}$ .? *Jan. 1881.*

The best experiment by which I could prove this

would be to heat phosphorus slowly to its boiling point,  $230^{\circ}\text{C}$ . At this temperature it assumes the red amorphous form. If the temperature be raised further to  $260^{\circ}\text{C}$ ., the red phosphorus is suddenly reconverted into ordinary phosphorus. This experiment is best performed in a tube filled with carbonic dioxide, or else hermetically sealed.

Or I might prove it in this way:—I should heat both in hydric nitrate till they are dissolved, and neutralise them with ammonia; then, by adding to both neutral solutions a few drops of argentic nitrate or cupric sulphate, the same precipitate is formed.

**386.** Describe the chief differences between the properties of the two varieties of phosphorus—red and clear phosphorus. *June 1866—Jan. 1878.*

The relative properties of the two varieties of phosphorus are:—

Clear Phosphorus.	Red Phosphorus.
Colour yellowish, like wax or amber.	From chocolate to scarlet.
Transparent.	Opaque.
Soluble in carbonic disulphide.	Insoluble in carbonic disulphide.
Phosphorescent in dry air.	Not phosphorescent.
Spontaneously inflammable in hot air ( $60^{\circ}\text{C}$ .)	Inflammable at $260^{\circ}\text{C}$ .
Poisonous,	Not poisonous.

## PHOSPHORIC PENTOXIDE.

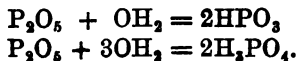
**387.** What are the principal compounds of phosphorus with oxygen? *July 1850—July 1859.*

**388.** Give the formula of the body which is formed when you burn phosphorus in an excess of oxygen. *June 1878.*

In a limited quantity of oxygen phosphorous trioxide (or anhydride,  $P_2O_3$ ) is formed. In an excess of oxygen phosphoric pentoxide (or anhydride,  $P_2O_5$ ) is formed. These two oxides, when combined with water, yield two powerful acids—hydric phosphite ( $H_3PO_3$ ) and hydric phosphate ( $H_3PO_4$ ).

**389.** What substance is formed when a piece of dry phosphorus is burnt in an excess of dry air? Give the formula of the phosphorus compound produced, and explain how it is acted upon by boiling water *Jan. 1873.*

When dry phosphorus is burned in an excess of dry air, phosphoric pentoxide is produced, which assumes the form of white flakes. The formula of this compound is  $P_2O_5$ . This body readily dissolves in hot water, hissing like a hot iron dipped into cold water, forming hydric metaphosphate ( $HPO_3$ ). If the water be boiling, more water is taken up by the phosphorus, and a solution of hydric orthophosphate is obtained ( $H_3PO_4$ ).



**390.** How could you detect phosphoric acid in an aqueous solution? *Jan.* 1882.

I should add to the solution **ammonic chloride, magnesian sulphate, and some ammonia.** If, on stirring, a white crystalline precipitate is formed, the aqueous solution contained phosphoric acid or hydric phosphate ( $\text{H}_3\text{PO}_4$ ).

**391.** Describe the experiments you would perform in order to decide whether the oxide formed by the combustion of phosphorus in oxygen is an acid or a base. *June* 1880.

I should first dissolve the oxide in water, obtaining thereby a body of the composition of  $\text{HPO}_3$ . I dip in this solution a strip of blue litmus paper, and at once it turns red—a clear proof that it is an acid. If, on the contrary, the oxide were a base, the blue litmus paper would remain unchanged, and a strip of red litmus paper would be turned blue.

Again, a solution of **caustic soda**, which changes the colour of litmus from red to blue, will **dissolve** it, forming a liquid which does not affect the colour of litmus, and which on evaporation yields crystals of a salt.

Lastly, if **added to a solution of sodic carbonate**, it takes the place of the carbonic dioxide, and is therefore similar to that body.

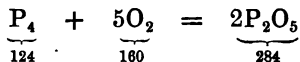
**392.** A piece of dry phosphorus is sealed up in a tube with atmospheric air and gently heated. **What is the action of the phosphorus in this experiment?** Describe the properties of the gas which is left. *June* 1864.

The phosphorus in this case combines with the oxygen of the air to form phosphoric pentoxide ( $\text{P}_2\text{O}_5$ ).

The gas which is left is nitrogen, for the properties of which refer to No. 137, Chap. IV.

**393.** How much anhydrous phosphoric acid is formed by the combustion of one gramme of phosphorus ( $P = 31$ )? How much pure air is needed for the production of this phosphoric acid? *Jan.* 1868.

The equation of the reaction is:—



Thus  $124 : 1 :: 284 : x$ ,

or  $x = 2.290$  grammes of phosphoric pentoxide.

Again,  $284 : 2.290 :: 160 : x$ ,

or  $x = 1.290$  grammes of pure oxygen.

And  $1.290$  grammes of pure oxygen corresponds to

$$\frac{1.290 \times 100}{23} = 5.610 \text{ grammes of pure air.}$$



## CHAPTER XX.

### HYDRIC PHOSPHIDE ( $\text{PH}_3$ ).

(Phosphine—Phosphamine—Phosphuretted Hydrogen.)

$$\frac{\text{Molecular weight, 34.}}{\text{Molecular volume, } \boxed{2}} = 17 \text{ sp. gr.}$$

Or 17 grammes of  $\text{PH}_3$  measure 11·2 litres.  
17 grains of  $\text{PH}_3$  measure 44·4 cubic inches.



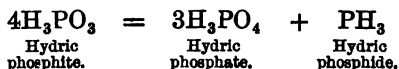
## HYDRIC PHOSPHIDE.

**394.\*** Give the various ways of preparing hydric phosphide.

1. By boiling together phosphorus with a solution of potassic hydrate or milk of lime. A little ether is added, to expel the air from the flask. The equation of the reaction is:—



2. By heating hydric phosphite in a glass retort.

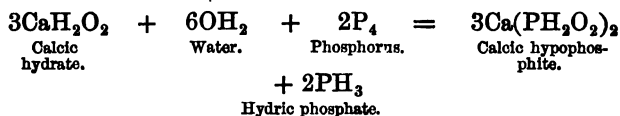


3. By throwing calcic phosphide into warm water the hydric phosphide escapes, owing to the decomposition of the calcic phosphide, which takes fire spontaneously at the surface of the water.

**395.** Explain the chemical reaction which takes place when phosphorus and milk of lime are boiled together. How do you account for ordinary phosphuretted hydrogen losing its property of spontaneous inflammability when kept for some time at a low temperature? *Jan. 1874.*

When these two substances are boiled together in a retort, the water of the milk of lime is decomposed,

part of its hydrogen uniting with the phosphorus to form hydric phosphide (phosphuretted hydrogen), while the rest, with the elements of calcic hydrate, combines with more phosphorus to form calcic hypophosphite. The reaction may be expressed thus:—



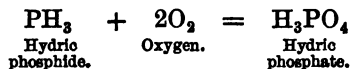
The reason why ordinary phosphuretted hydrogen loses the property of spontaneous inflammability is this: The liquid hydric phosphide ( $\text{P}_2\text{H}_4$ ), to the presence of which the inflammability is due, becomes condensed to a liquid form when kept for some time at a low temperature.

**396.** Give the formula of phosphuretted hydrogen, and describe its physical and chemical character, employing symbols to illustrate the reactions. *June 1881.*

Its formula is  $\text{PH}_3$ .

Its *physical characters* are: It is a colourless gas; it has a strong smell of garlic or rotten fish.

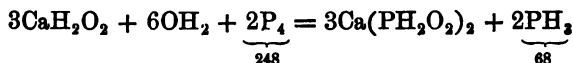
Its *chemical characters* are: It neither supports combustion nor life. It takes fire spontaneously when mixed with  $\text{PH}_2$  or  $\text{P}_2\text{H}_4$ , as it is under ordinary circumstances; but when pure it does not do so. The result of the combustion with the oxygen of the air is:—



This combination is accompanied by a beautiful flame, which changes into wreaths of white smoke rising in the air, and widening as they ascend higher and higher.

**397.** How much phosphuretted hydrogen ( $\text{PH}_3$ ) by weight and by volume would be furnished by 31 grammes of phosphorus, supposing all the phosphorus to be converted into the gas? *Jan. 1872.*

The equation of the reaction is:—

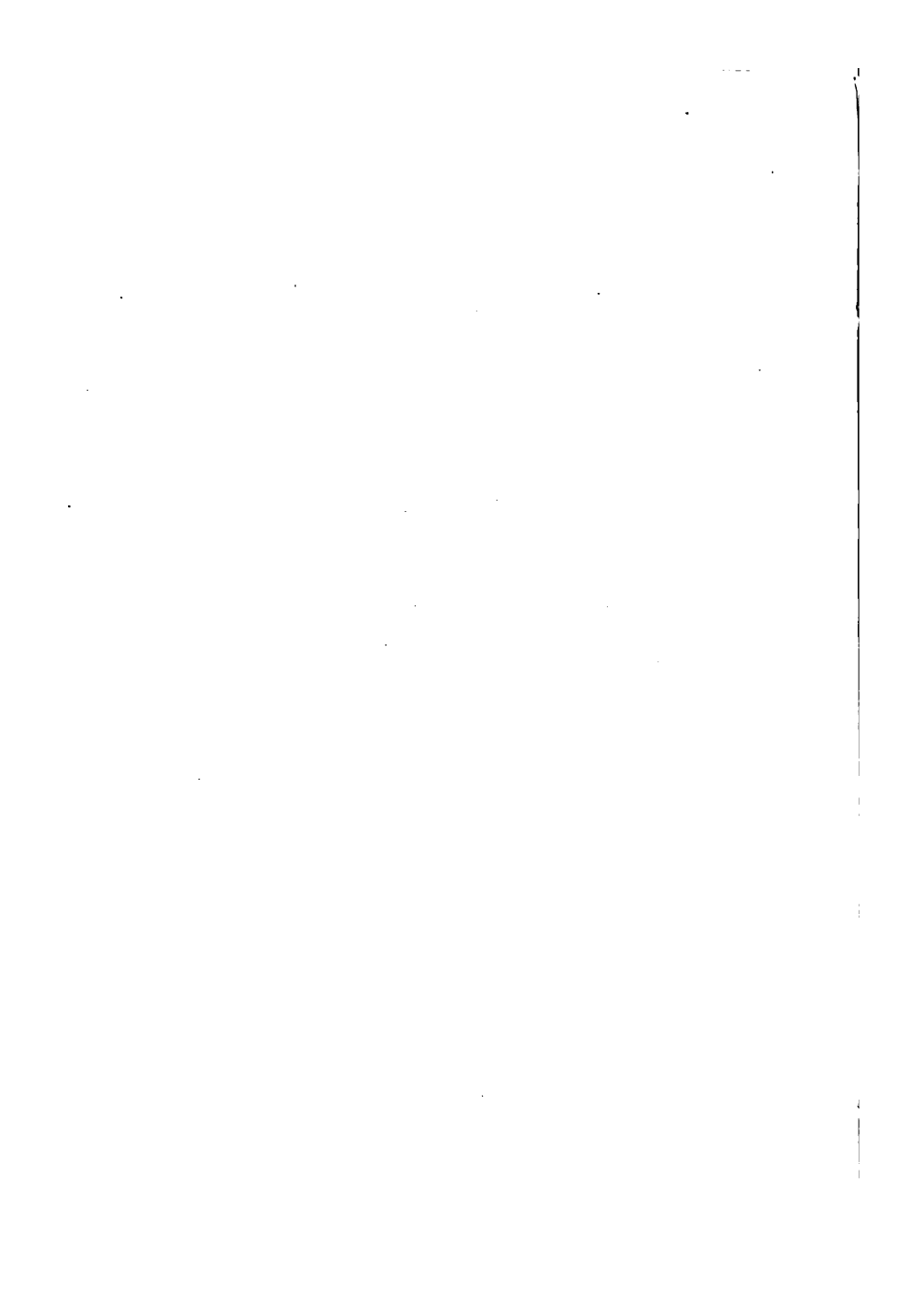


Thus  $248 : 68 :: 31 : x$ , or  $x = 8.5$  grammes of hydric phosphide (phosphuretted hydrogen).

But if 17 grammes of  $\text{PH}_3$  occupy 11.2 litres

$$8.5 \text{ or } \frac{17}{2} \quad " \quad " \quad " \quad \frac{11.2}{2} \text{ or}$$

5.6 litres of hydric phosphide.



## CHAPTER XXI.

### LIGHT CARBURETTED HYDROGEN ( $\text{CH}_4$ ).

(Marsh Gas---Methylic Hydride.)

$$\frac{\text{Molecular weight, 16.}}{\text{Molecular volume, } \boxed{\phantom{00}}} = 8 \text{ sp. gr.}$$

Or 8 grammes of  $\text{CH}_4$  measure 11.2 litres.  
8 grains of  $\text{CH}_4$  measure 44.4 cubic inches.



## LIGHT CARBURETTED HYDROGEN.

**398.** What are the natural and artificial sources of marsh gas? *Jan.* 1860.

The *natural sources* of marsh gas are stagnant pools in which there is a great quantity of decayed organic matter. By stirring the mud the gas rises, mixed with nitrogen and carbonic dioxide. In coal mines it also exists, imprisoned within the seams of coal. When mixed with air it occasions those disastrous explosions so frequent in the collieries of our country. The miners call it fire-damp.

The *artificial sources* of marsh gas, among others, are coal gas and any acetate, from which body it is usually prepared in the laboratories.

**399.\*** What precaution is taken against the explosion of the fire-damp in the coal mines?

Miners use **Davy's safety lamp**, which is a common oil lamp covered with a cage of wire gauze. The wire gauze being a good conductor of heat, cools the flame and thus prevents the flame within the lamp from setting fire to the explosive mixture without. At the same time the flame within is seen to enlarge, and when the explosive gas is in sufficient excess to the air the lamp is extinguished, and thus a timely warning is given to the miner of the danger.



That is to say that 2 vol. of  $\text{CH}_4$  require 4 vol. of  $\text{O}$ , or 20 vol of air.

$\therefore$  1 vol. of  $\text{CH}_4$  requires  $\frac{20}{2} = 10$  vol. of air.

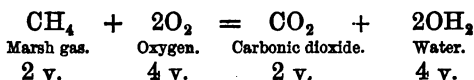
**402.** How much pure air ought to be mixed with 100 measures of fire-damp (marsh gas) in a coal mine, in order to supply material for the complete combustion of the marsh gas during the explosion? *June 1868.*

Since the amount of air required for the complete combustion of fire-damp is 10 times its volume, 100 measures of fire-damp, in order to be completely burned, will require  $100 \times 10$  or **1,000 measures of air.**

**403.** How much oxygen do you require for the complete combustion of 10 cubic centimetres of marsh gas? How many cubic centimetres of each product of the combustion would be formed? *June 1871.*

For the complete combustion of 10 cubic centimetres of marsh gas I require  $10 \times 10 = 100$  cubic centimetres of air, or  $\frac{100}{5} = \mathbf{20}$  cubic centimetres of oxygen.

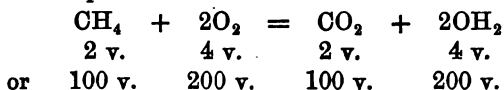
According to the equation of the reaction,



there would be produced 4 v. of vapour of water, which measure **20 cubic centimetres**; and 2 v. of carbonic dioxide, which measure **10 cubic centimetres.**

**404.** If 100 volumes of marsh gas be exploded with 400 volumes of oxygen, what bulk of gas will remain, and of what will it consist? *Jan. 1877.*

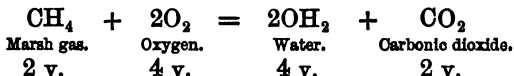
The equation of the reaction is:—



Marsh gas thus requires for its complete combustion double its volume of oxygen. Therefore, by exploding 100 volumes of marsh gas with 400 of oxygen, there will remain in the jar a bulk of 300 volumes of gas. It will consist of **100 volumes of carbonic dioxide**, the result of the combustion, and the **200 volumes of free oxygen** which was left uncombined, the steam having been condensed to water.

**405.** If two volumes of marsh gas, weighing 16 grams, be burnt in excess of air, how many volumes of carbonic dioxide (carbonic acid) are produced? Also, what is the weight of the other compound formed at the same time? *June 1876.*

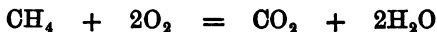
The reaction is represented by the following equation:—



From the inspection of the equation it may be gathered that **2 volumes of carbonic dioxide** are produced. The other compound formed is 4 volumes of steam.

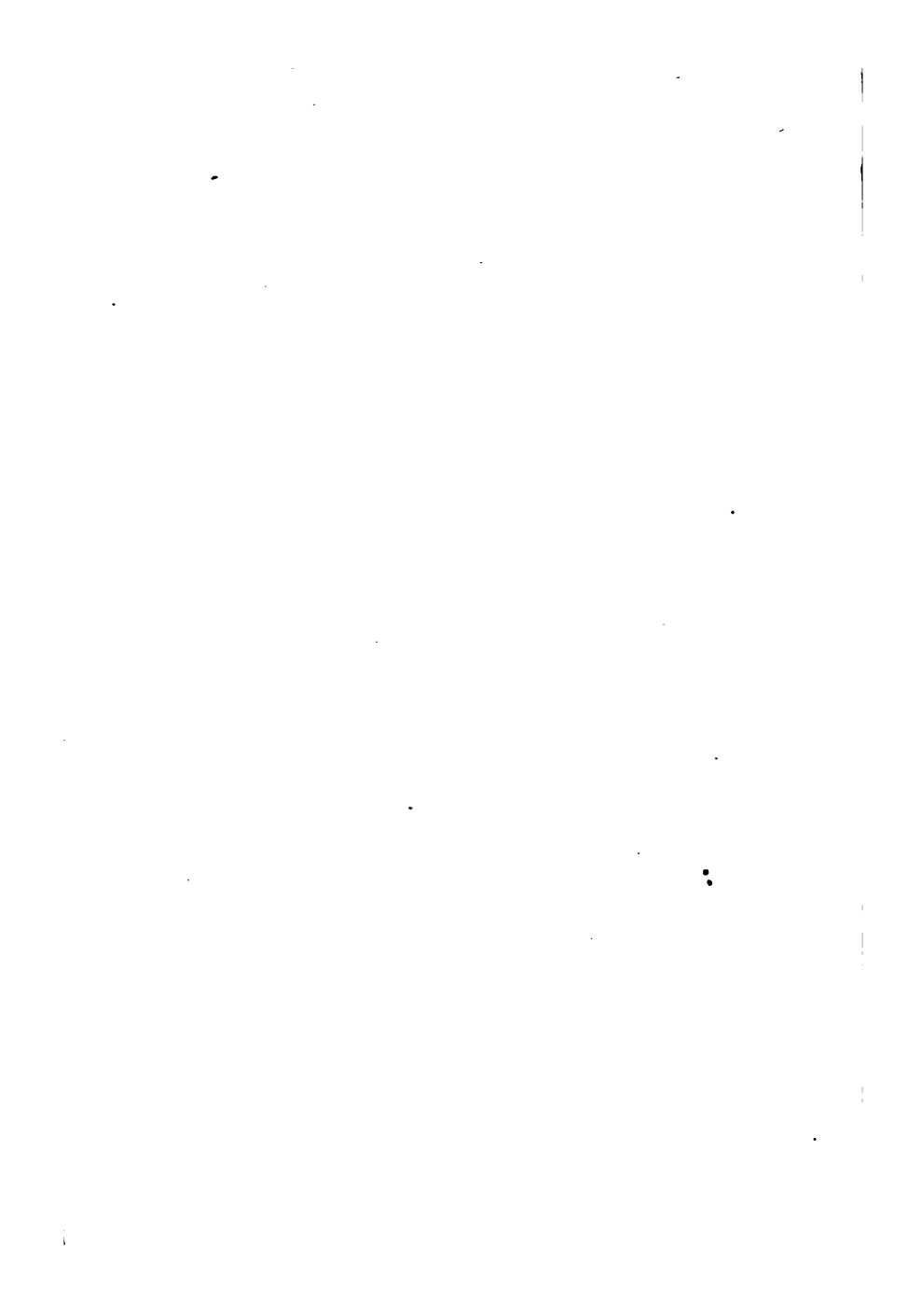
If 2 volumes of marsh gas should weigh 16 grammes, then 2 volumes of steam will weigh 18 grammes, and therefore 4 volumes of steam weigh **36 grammes**.

**406.** Explain the meaning of the following equation:—



*June 1873.*

This means that light carburetted hydrogen combines with twice its volume of oxygen to form carbonic dioxide and vapour of water. This reaction often takes place, with great loss of life, in coal mines, where the gas has been imprisoned for thousands of years. The miners call it fire-damp. By the application of a light it takes fire, and a fearful explosion ensues. But, unfortunately, the survivors of this first calamity are then subject to perhaps a more fatal one—that is, to the deadly effects of carbonic dioxide, which is the result of the combination of the light carburetted hydrogen with oxygen. In the language of miners the carbonic dioxide is called *after damp*, or *choke damp*.



## CHAPTER XXII.

### HEAVY CARBURETTED HYDROGEN ( $C_2H_4$ ).

(Olefiant Gas—Ethylene.)

$$\frac{\text{Molecular weight, 28.}}{\text{Molecular volume, } \boxed{\phantom{00}}} = 14 \text{ sp. gr.}$$

Or 14 grammes of  $C_2H_4$  measure 11·2 litres.  
14 grains of  $C_2H_4$  measure 44·4 cubic inches.



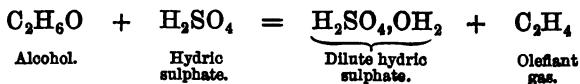
## HEAVY CARBURETTED HYDROGEN.

**407.** What is the composition of olefiant gas, and how is it ascertained? *June 1875.*

Olefiant gas is composed of 2 atoms of carbon and 4 atoms of hydrogen. It is represented by the formula  $C_2H_4$ . That it contains carbon and hydrogen is easily proved by burning olefiant gas with chlorine. On application of a light it burns with a smoky flame, depositing at the same time within the jar a great amount of soot. This proves the presence of carbon. Then the gas which remains in the jar is easily proved to be hydric chloride by presenting to it a rod dipped in ammonia, when dense white fumes are given off, thus proving the presence of hydrogen in olefiant gas.

**408.** How is olefiant gas prepared? *June 1875—Jan. 1878.*

It is prepared by mixing in a flask ordinary alcohol with strong hydric sulphate. After having applied a gentle heat the liquid becomes dark, and soon olefiant gas is evolved with great rapidity. The equation of the reaction is:—



The office of the hydric sulphate in this case seems

to be that of splitting up the alcohol into water and olefant gas, for the former of which it always has a great attraction.

Sometimes a little sand is added, in order to lessen the tendency to froth up towards the end of the action.

**409.** Mention the distinguishing characters of heavy carburetted hydrogen. *June 1875—Jan. 1878.*

It is a colourless, invisible gas, possessing a sweetish taste, and is but slightly soluble in water. It is not a supporter of combustion, but in contact with air burns with a more luminous flame than that of the light carburetted hydrogen. The results of the combustion are carbonic dioxide and water. To burn completely it needs 3 times its bulk of oxygen, i.e. 15 times that of air. This combustion takes place on application of a light, with a powerful detonation.

It combines *readily* with an equal volume of chlorine to form an oily liquid—ethylenic dichloride ( $C_2H_4Cl_2$ ); hence its name of olefant gas.

It combines, *on application of a light*, with twice its volume of chlorine, burning with a smoky flame and at the same time depositing within the jar a large amount of soot.

**410.** Why does olefant gas burn with a brighter flame than hydrogen? *June 1866.*

The brightness of a flame is due to three causes, separately or conjointly—the density of the combustible gases, their pressure, and the quantity of solid matter in incandescence.

In this case the reason would be the density of olefant gas, which is 14 times greater than that of

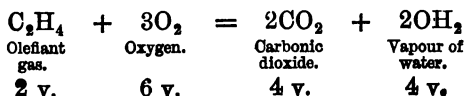
hydrogen. For a similar reason olefiant gas burns with a brighter flame than marsh gas does.

**411.** By what means could you convince yourself that olefiant gas contains twice as much carbon as an equal bulk of marsh gas does? *Jan. 1878.*

I could convince myself of it by introducing into one eudiometer 10 c. inches of marsh gas mixed with 20 c. inches of oxygen, and into another eudiometer 10 c. inches of olefiant gas mixed with 30 c. inches of oxygen. Now I cause these gases to combine through the electric spark, and there is formed in both tubes steam, which condenses, and carbonic dioxide, which causes lime-water to become turbid, thus proving that it contains carbon. Moreover, the lime-water, by the absorption of carbonic dioxide, causes the water in the eudiometers to rise. Now in that containing previously the olefiant gas the water rises twice as high as in that containing the marsh gas, thus proving that a double quantity of carbonic dioxide has been formed, and consequently that olefiant gas contains twice as much carbon as marsh gas.

**412.** How many c.c. of oxygen gas are required for the complete combustion of 200 c.c. of olefiant gas? What products are formed, and how many c.c. of each do you obtain? *June 1879.*

For the complete combustion of olefiant gas 3 times its volume of oxygen is required. The result of the combustion may be expressed by the following equation:—



From the inspection of the equation it will be seen that 200 c.c. of olefiant gas require 600 c.c. of oxygen, that the products formed are carbonic dioxide and vapour of water, and that there will be 400 c.c. of the first and 400 c.c. of the second gas.

**413.** A gas is composed of 92·3 parts of carbon and 7·7 parts of hydrogen. How many atoms of hydrogen are united in this gas to two atoms of carbon? *June 1879.*

The weight of 2 atoms of carbon being 24, we may find the answer by solving the following proportion :—

$$92\cdot3 : 7\cdot7 :: 24 : x, \text{ or } x = 2;$$

that is to say, 2 atoms of hydrogen are united in that gas to 2 atoms of carbon, which will be represented by the formula  $C_2H_2$  (acetylene).

#### LIST OF THE MOST IMPORTANT ELEMENTS.

##### *Non-Metallic Elements.*

Name.	Symbol.	Atomic Weight.
Oxygen . .	O .	16
Hydrogen . .	H .	1
Nitrogen . .	N .	14
Carbon . .	C .	12
Sulphur . .	S .	32
Chlorine . .	Cl .	35·5
Bromine . .	Br .	80
Iodine . .	I .	127
Phosphorus . .	P .	31
Boron . .	B .	11
Silicon . .	Si .	28

*Metallic Elements.*

Name.	Symbol.	Atomic Weight.	Latin Name.
Potassium . . .	K .	39 .	Kalium.
Sodium . . .	Na .	23 .	Natrium.
Silver . . .	Ag .	108 .	Argentum.
Barium . . .	Ba .	137 .	
Calcium . . .	Ca .	40 .	
Magnesium . . .	Mg .	24 .	
Zinc . . .	Zn .	65 .	
Iron . . .	Fe .	56 .	Ferrum.
Manganese . . .	Mn .	55 .	
Aluminium . . .	Al .	27·5 .	
Copper . . .	Cu .	63·5 .	Cuprum.
Lead . . .	Pb .	207 .	Plumbum.
Mercury . . .	Hg .	200 .	Hydrargyrum.
Gold . . .	Au .	196 .	Aurum.
Bismuth . . .	Bi .	210 .	
Arsenic . . .	As .	75 .	
Antimony . . .	Sb .	122 .	Stibium.
Tin . . .	Sn .	118 .	Stannum.
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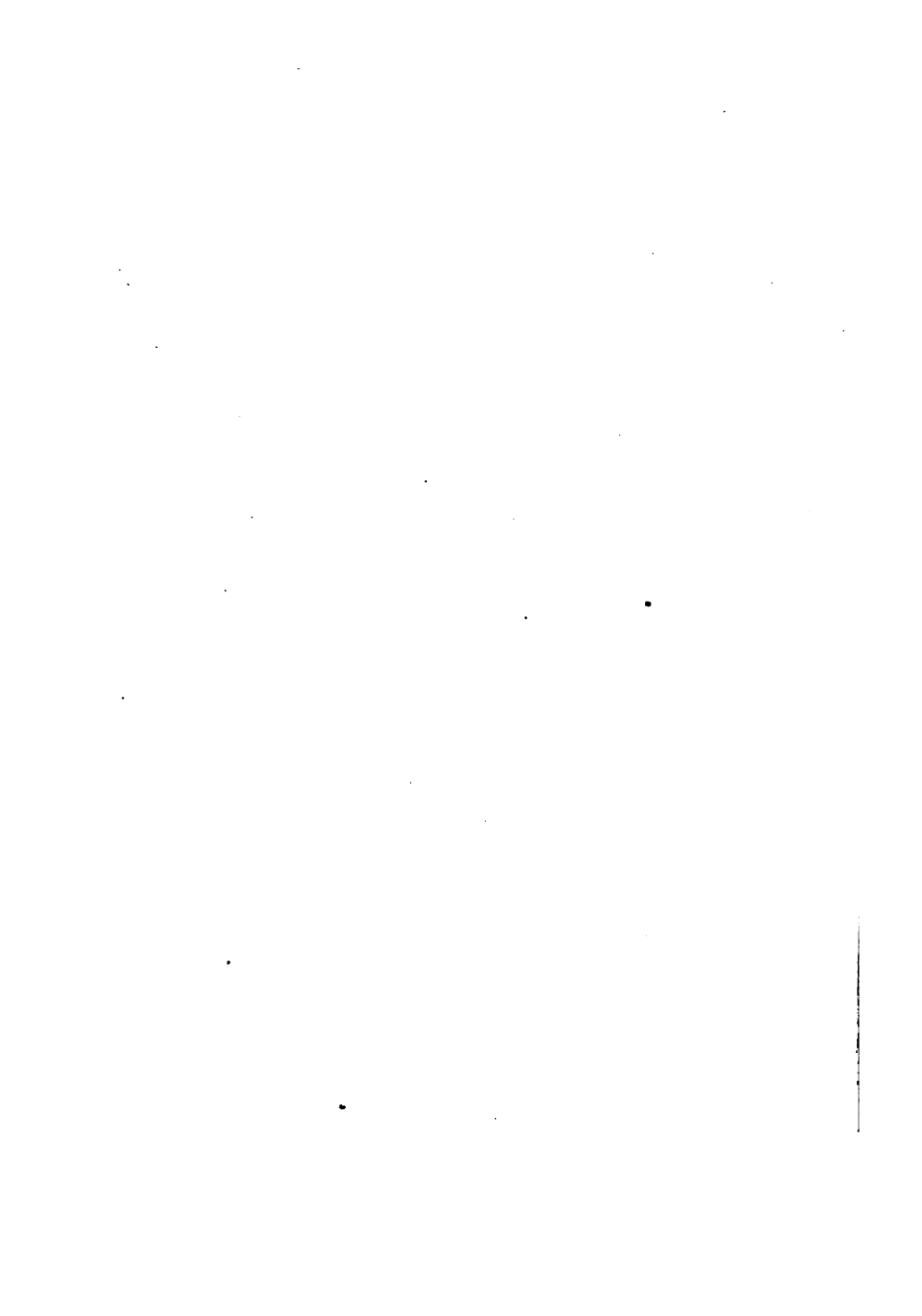
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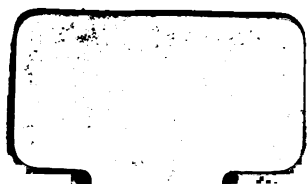
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The aim of this study was to determine the prevalence of *S. flexneri* in the United Kingdom. The study was designed to determine the prevalence of *S. flexneri* in the United Kingdom. The study was designed to determine the prevalence of *S. flexneri* in the United Kingdom. The study was designed to determine the prevalence of *S. flexneri* in the United Kingdom.

#### Methods

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